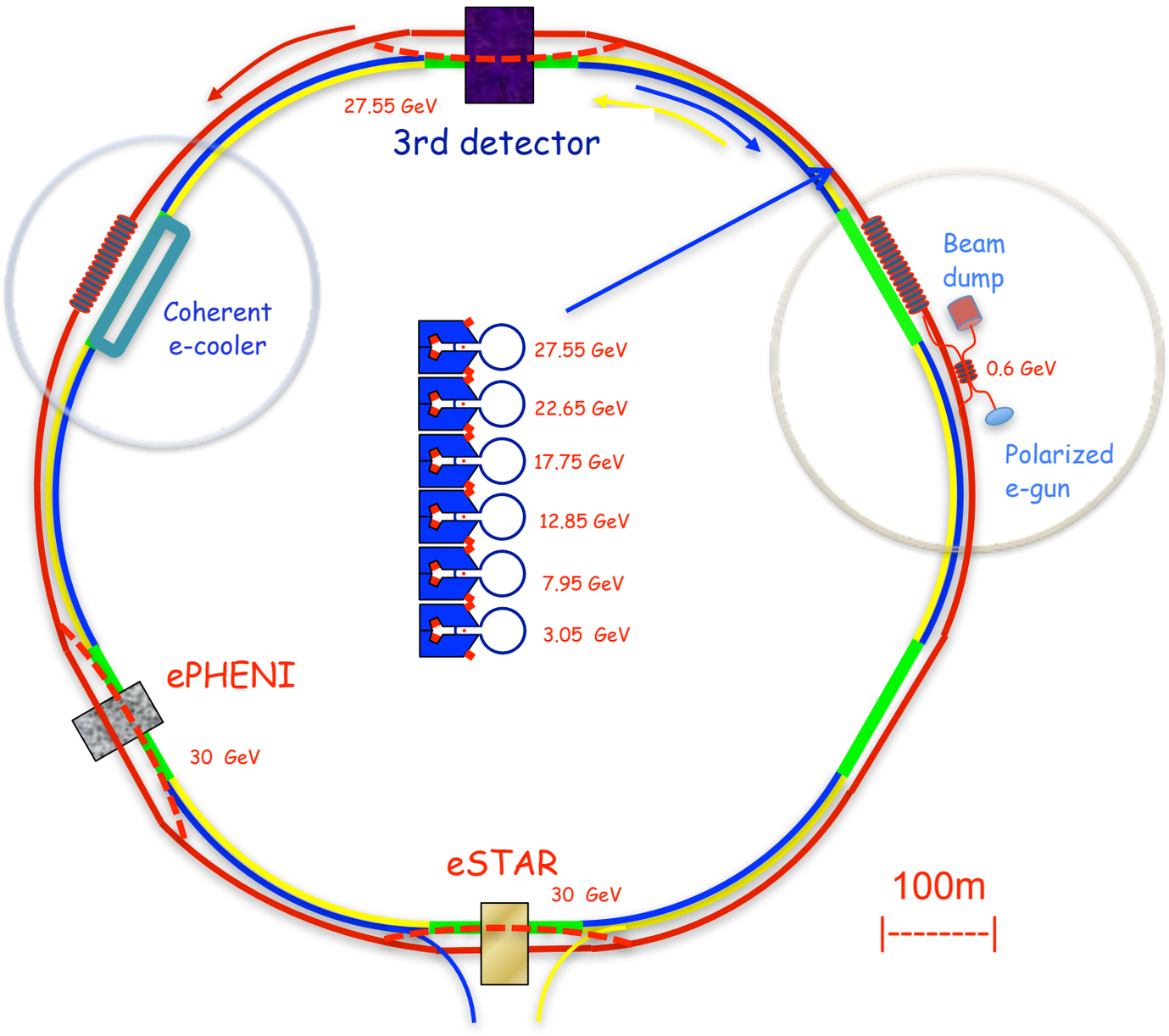
Studying Nucleon Structure with an Electron-Ion Collider

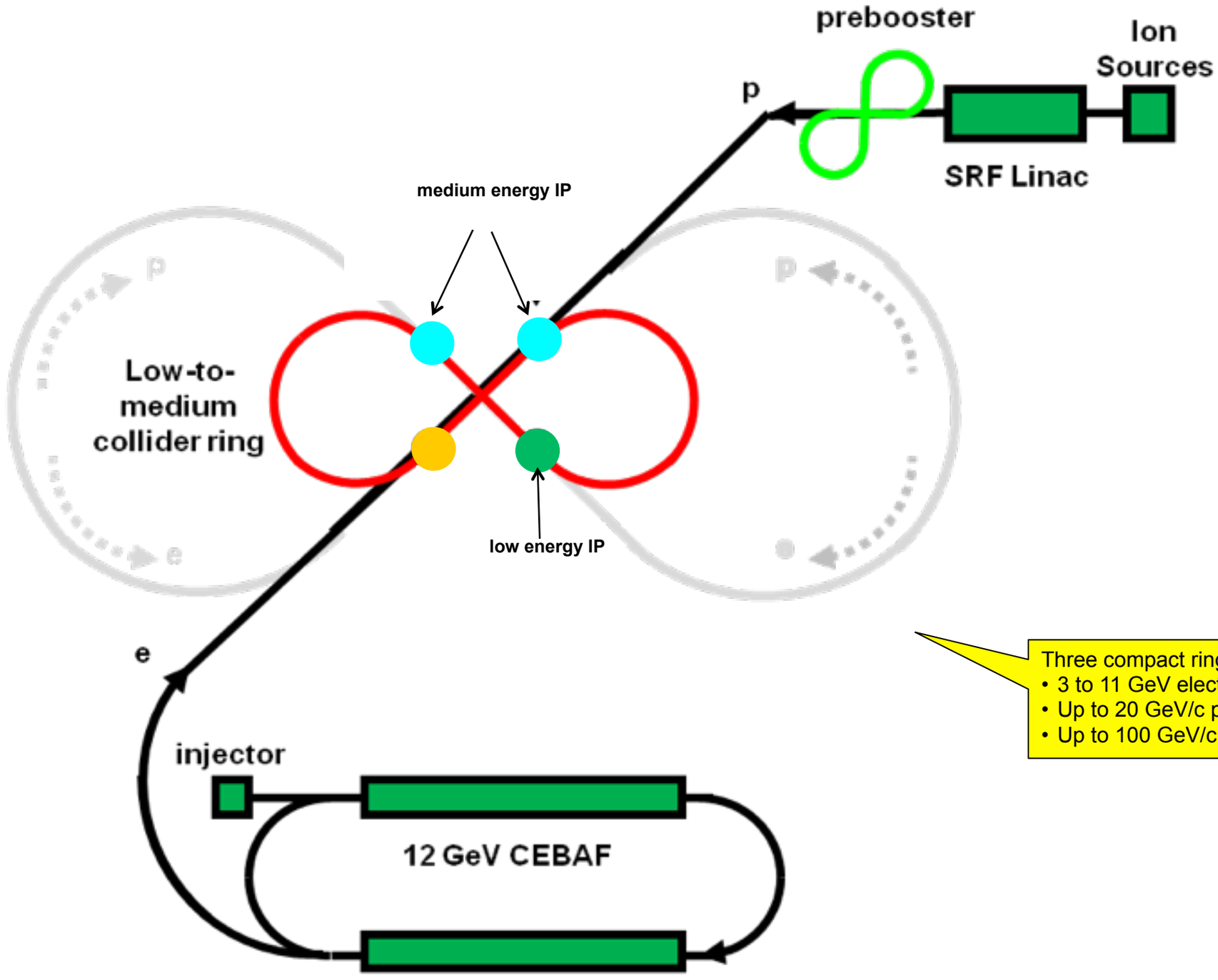
Thomas Burton
GHP 2011
Thursday 28th April 2011

eRHIC



V.N. Litvinenko, January 24, 2011

MEIC @ JLab



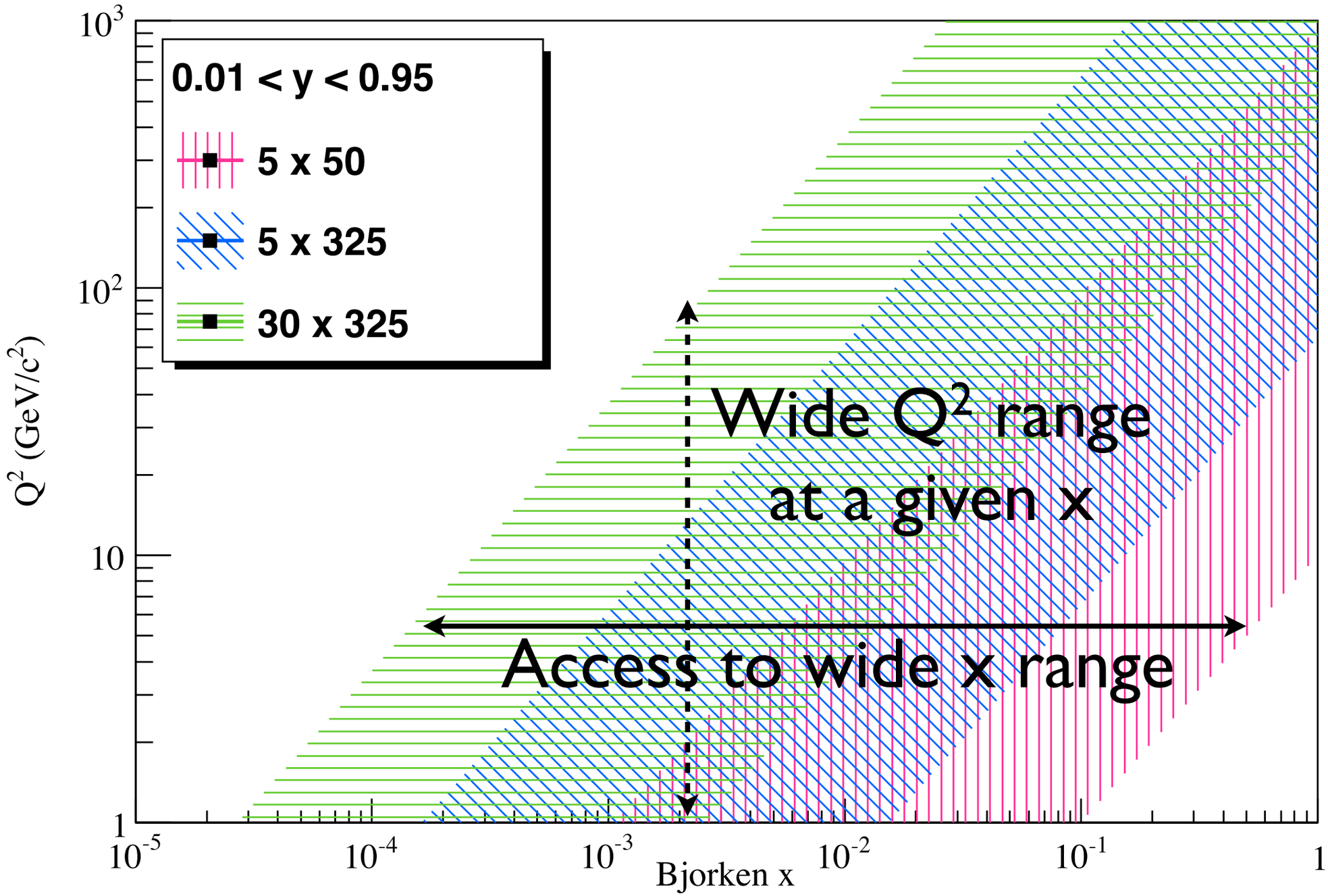
Three compact rings:
- 3 to 11 GeV electron
- Up to 20 GeV/c proton (warm)
- Up to 100 GeV/c proton (cold)

Energies, luminosities...

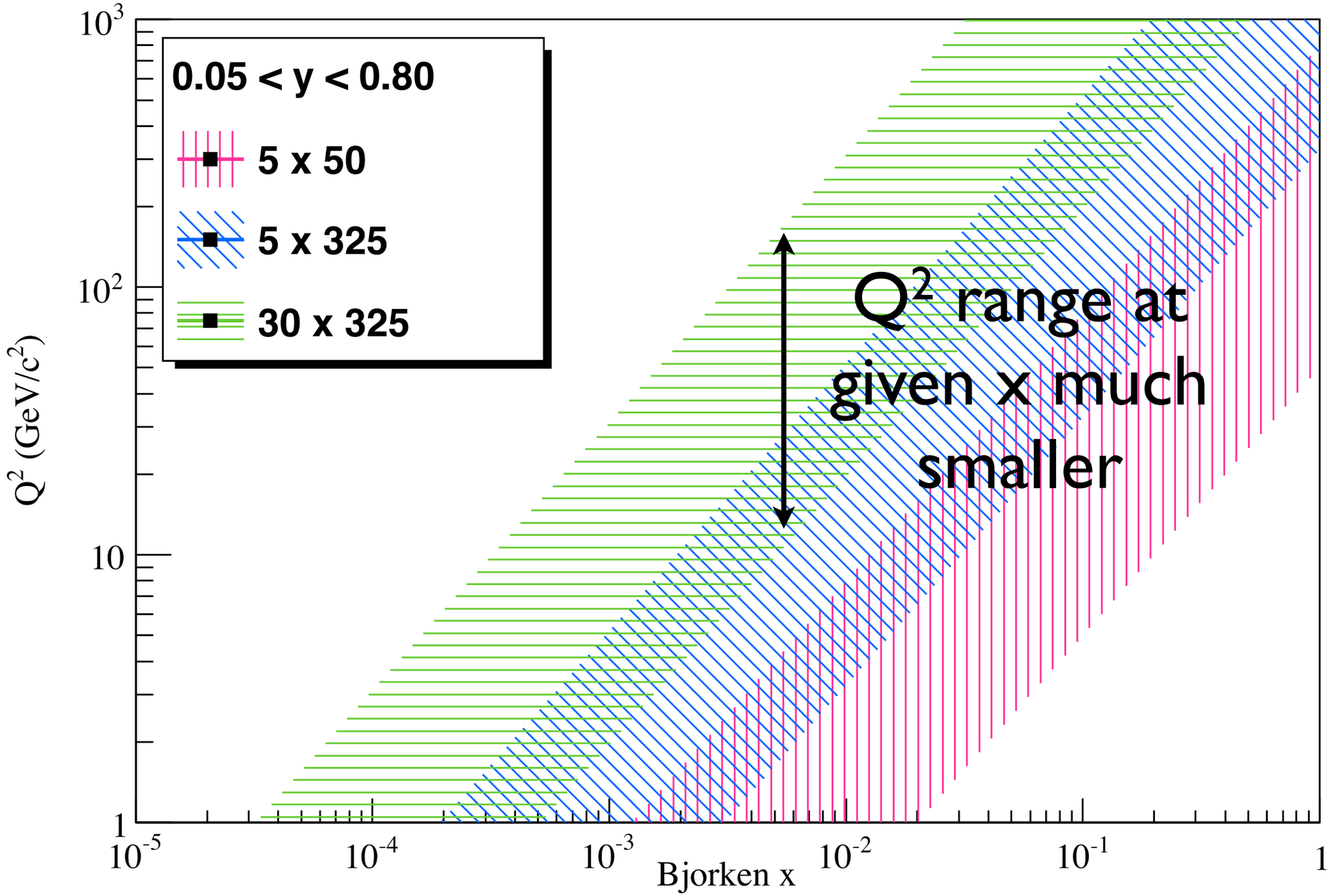
- Variable energy
- eRHIC 5x50 to 30x325 --> 30 to 200 GeV
- ELIC 3x20 to 11x100 --> 15 to 66 GeV
- L 10^{33} to 10^{34} cm^{-2} s^{-1}.

- <Put in table of E, L...>

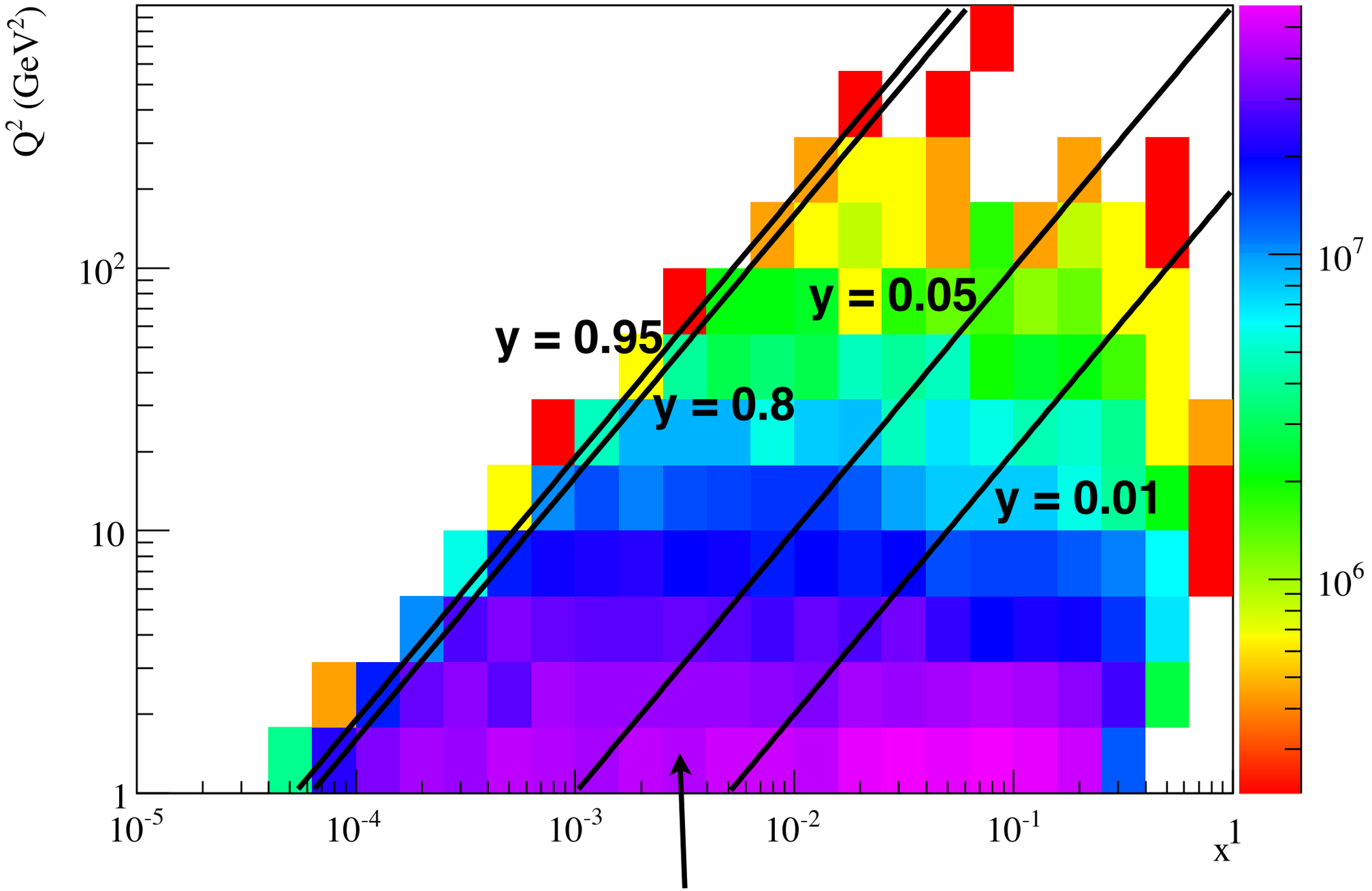
eRHIC Q^2-x span



Desire wide y range

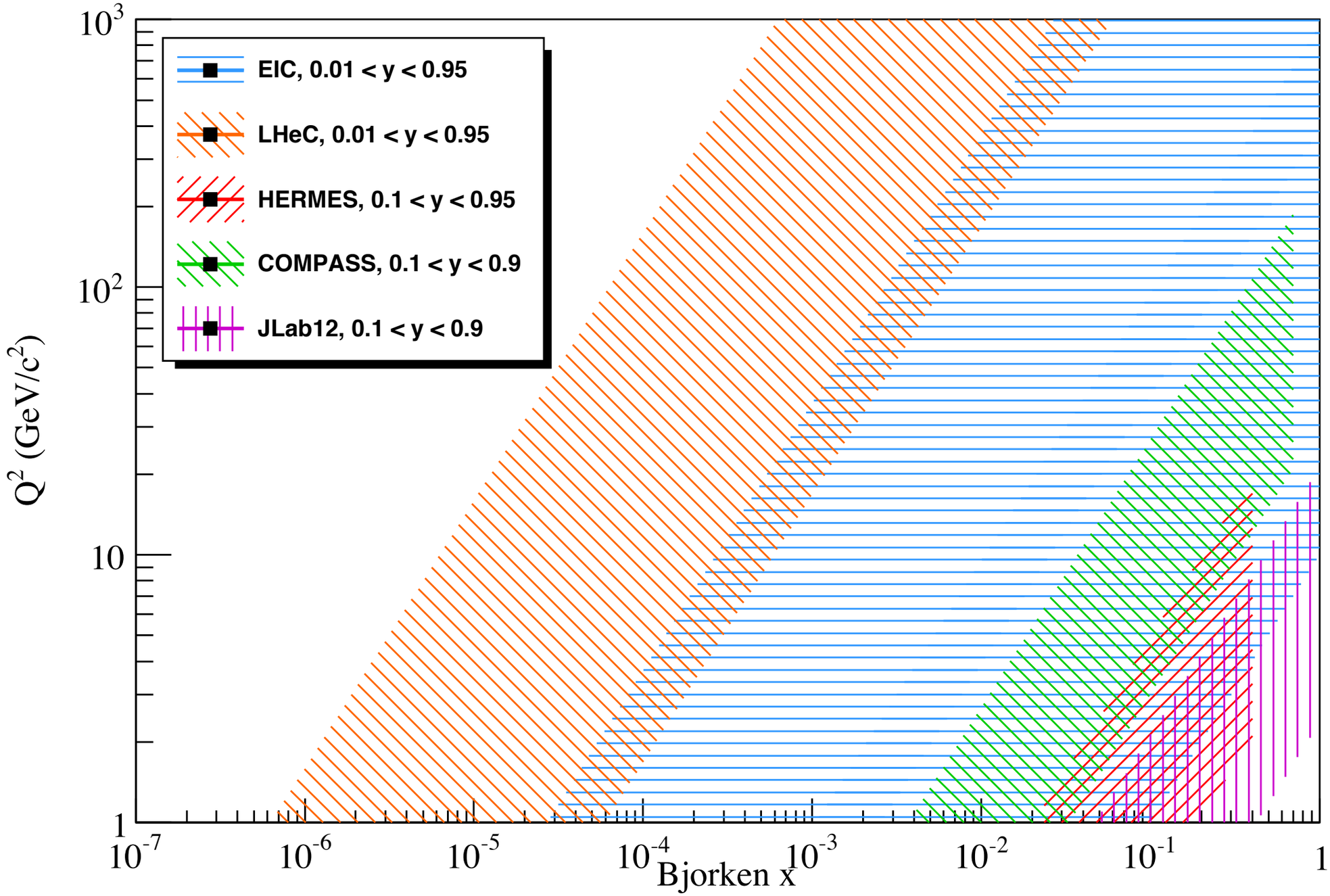


Q^2 vs. Bjorken x, 4 fb^{-1} at 20 x 250 GeV



Very high statistics bin-by-bin

Complementarity



Longitudinal structure function: F_L

$$\sigma_r = F_2\left(x, Q^2\right) - \frac{y^2}{Y_+} F_L\left(x, Q^2\right)$$

$$Y_+ = 1 + (1-y)^2$$

- Contributes significantly only at large *y*

- Use variable s at fixed x, Q^2

  - σ_r slope vs. y^2/Y_+ ➟ F_L

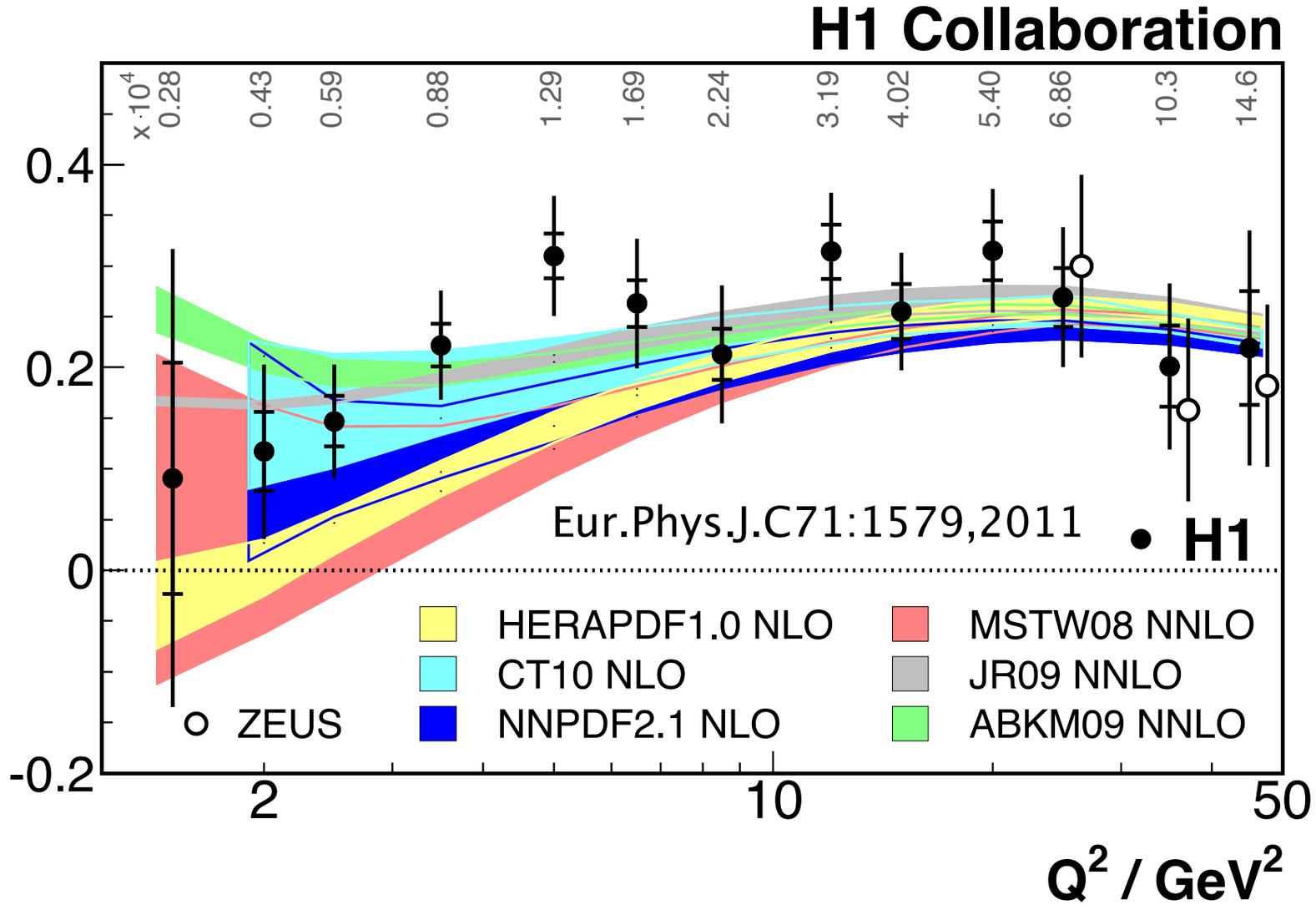
$$Q^2 = sxy$$

- EIC strength

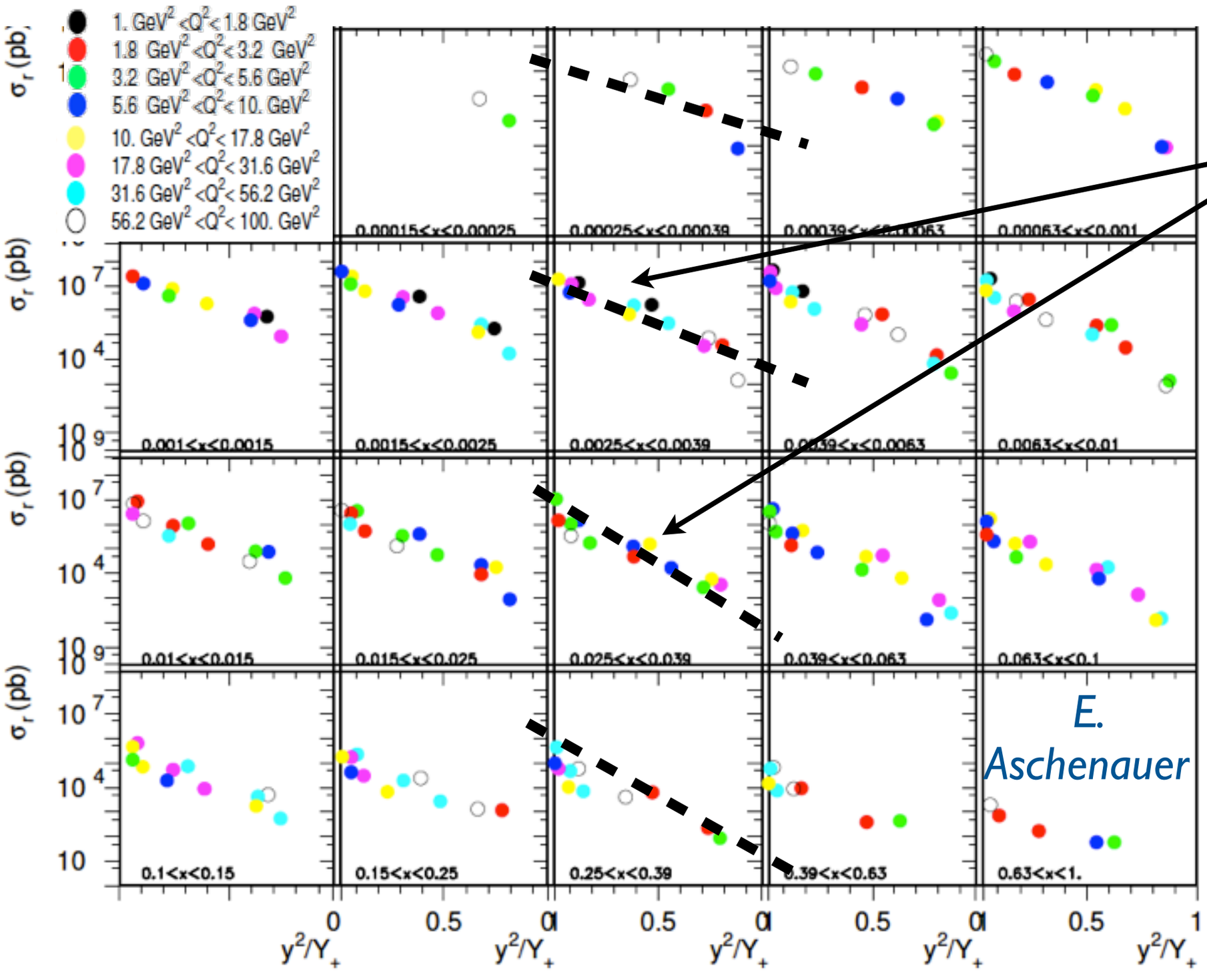
  - e.g. eRHIC $\sqrt{s}$ = 30-200 GeV

F_L

- Measured at HERA, but precision limited



Feasibility study



Measure slopes

Statistical uncertainties smaller than points

Under refinement - how well can we do?

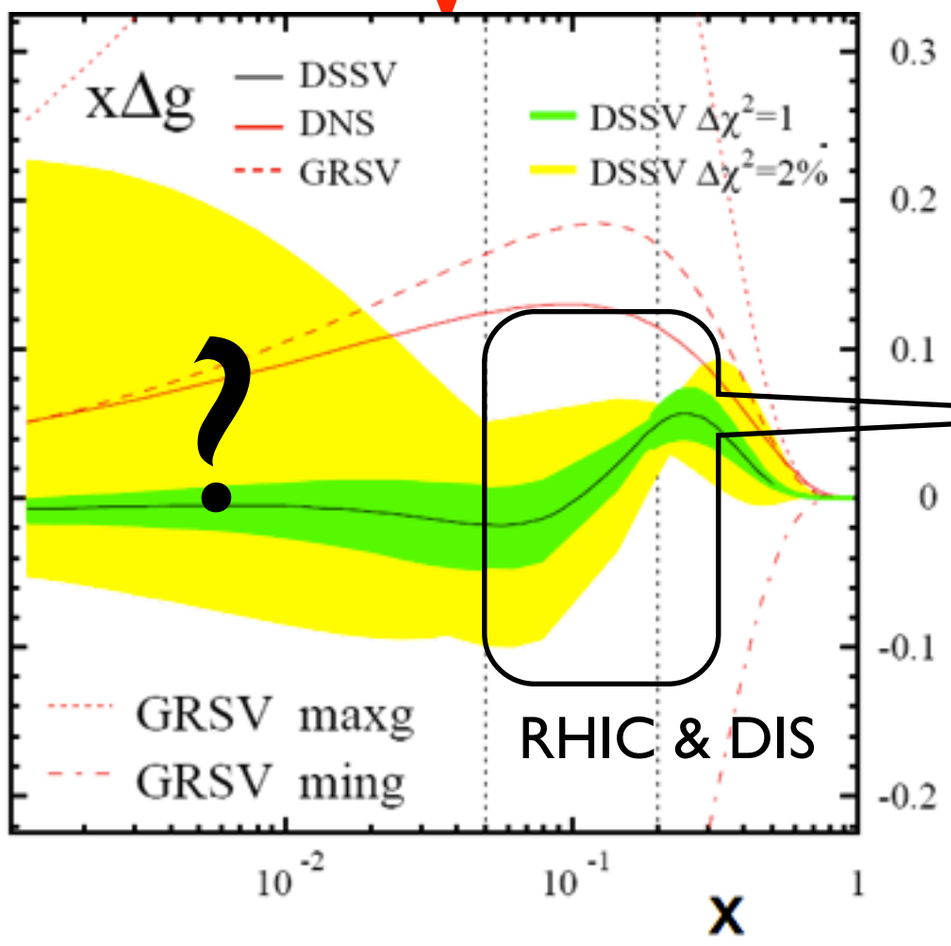
E. Aschenauer

$$Y_+ = 1 + (1-y)^2$$

Gluon polarisation

30%

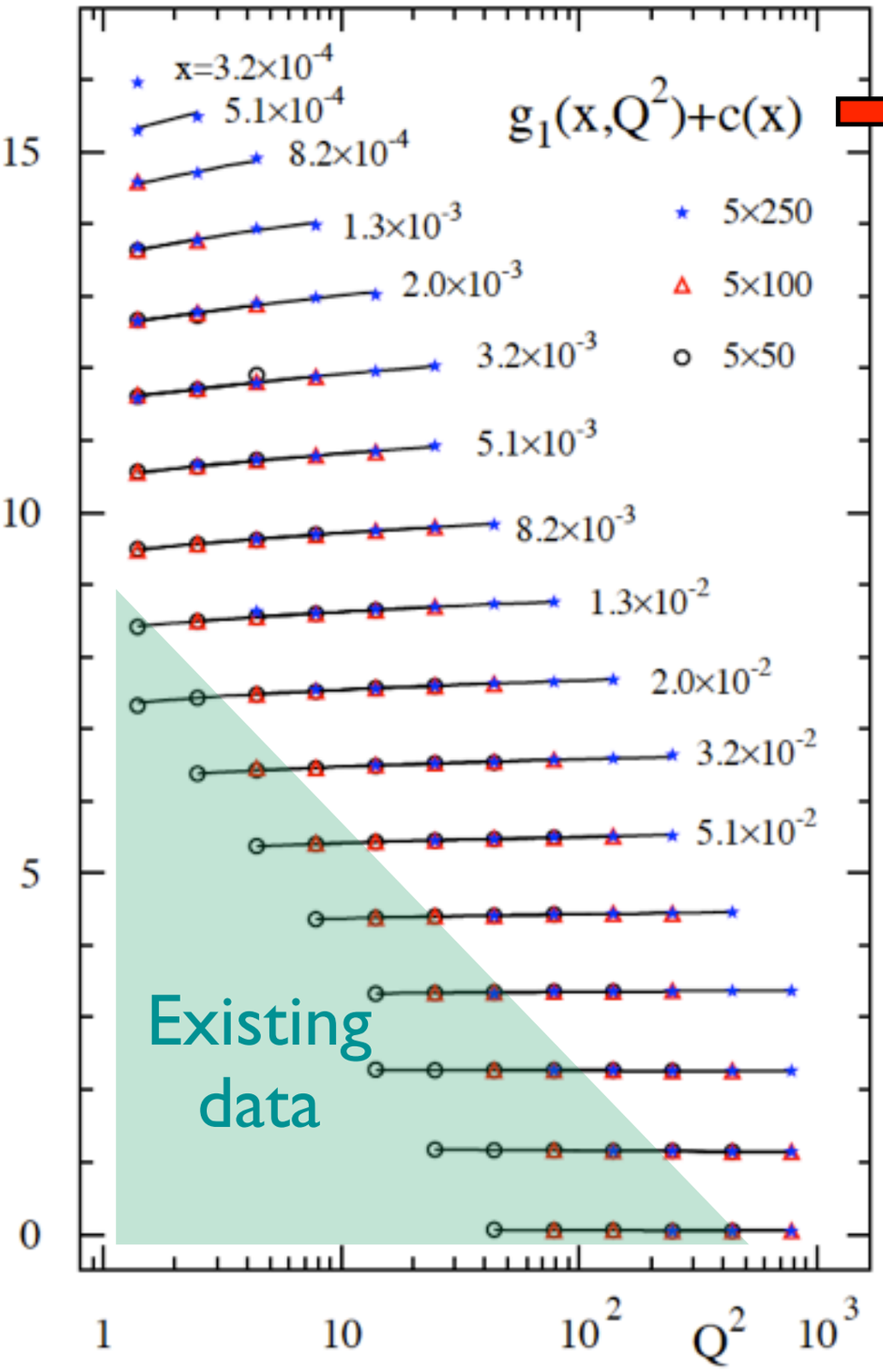
$$\frac{1}{2} = S_q + S_g + L_q + L_g$$



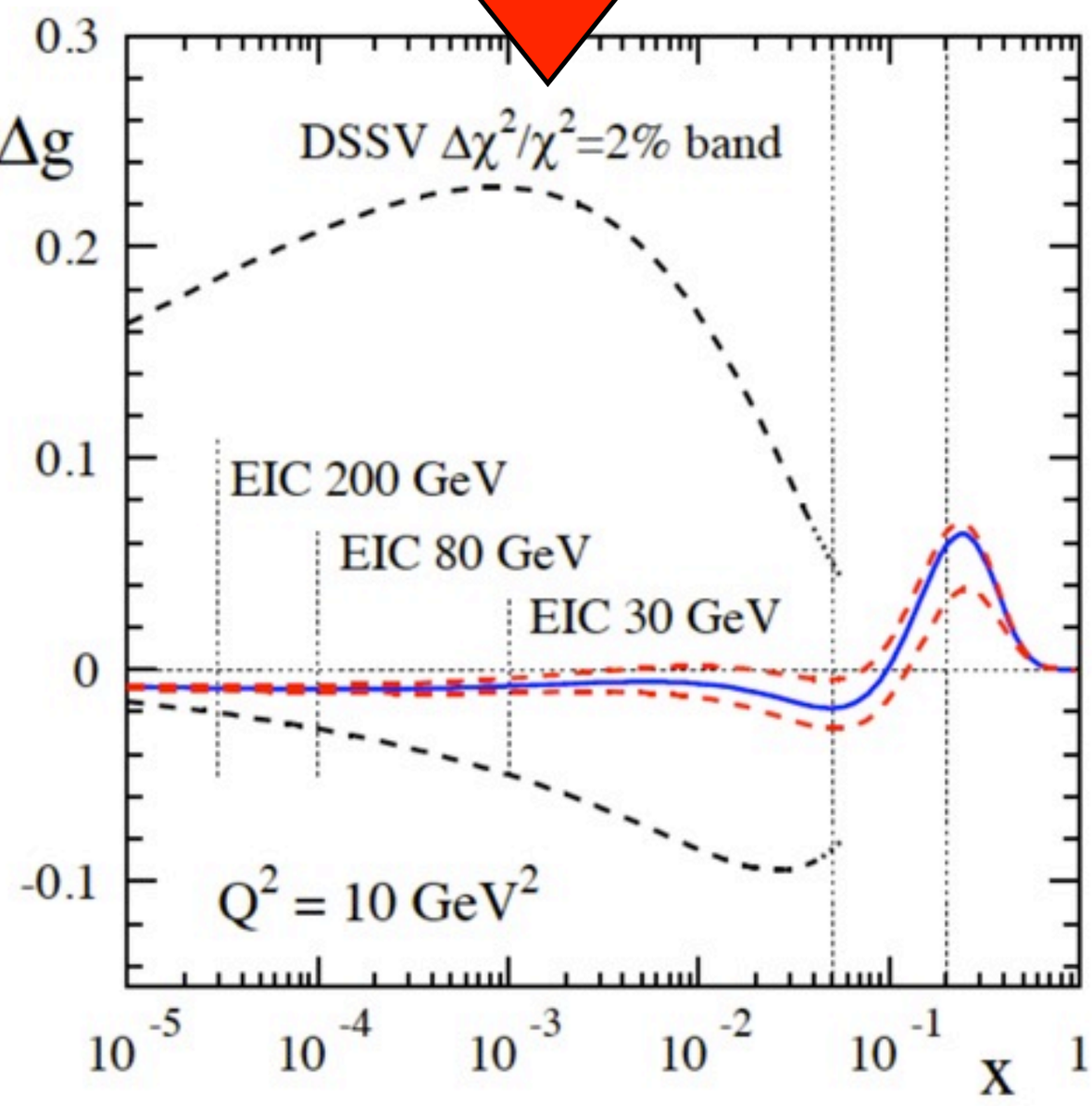
$$\int_{0.05}^{0.2} \Delta g(x, Q^2) dx \approx 0$$

$$\int_{0}^{1} \Delta g(x, Q^2) dx = \ldots ?$$

Pseudodata study

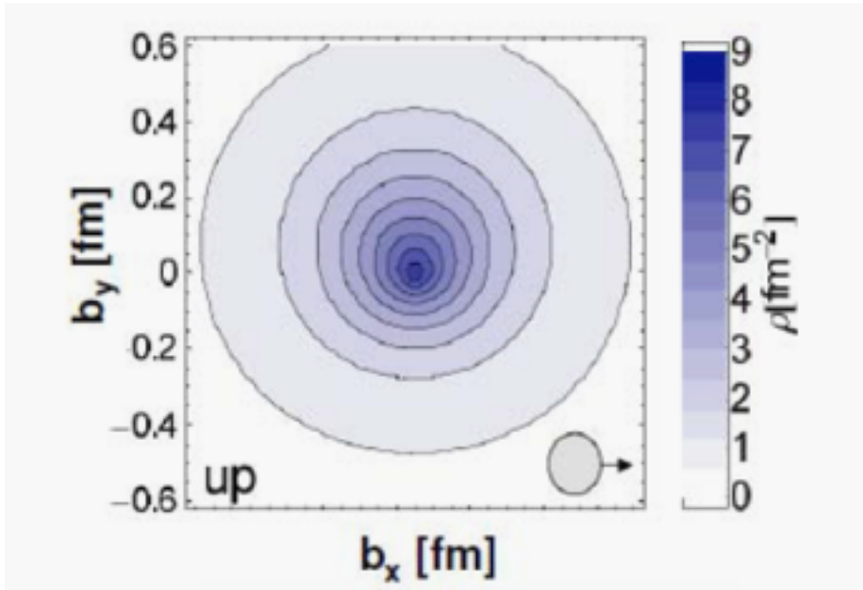


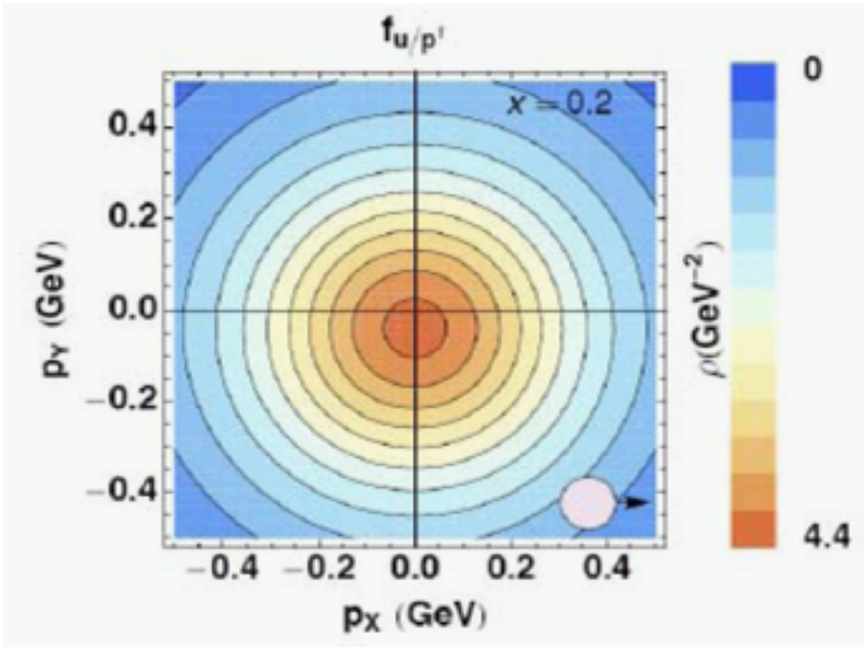
$$\frac{dg_1}{d\log\left(Q^2\right)} \propto -\Delta g\left(x, Q^2\right)$$



Imaging

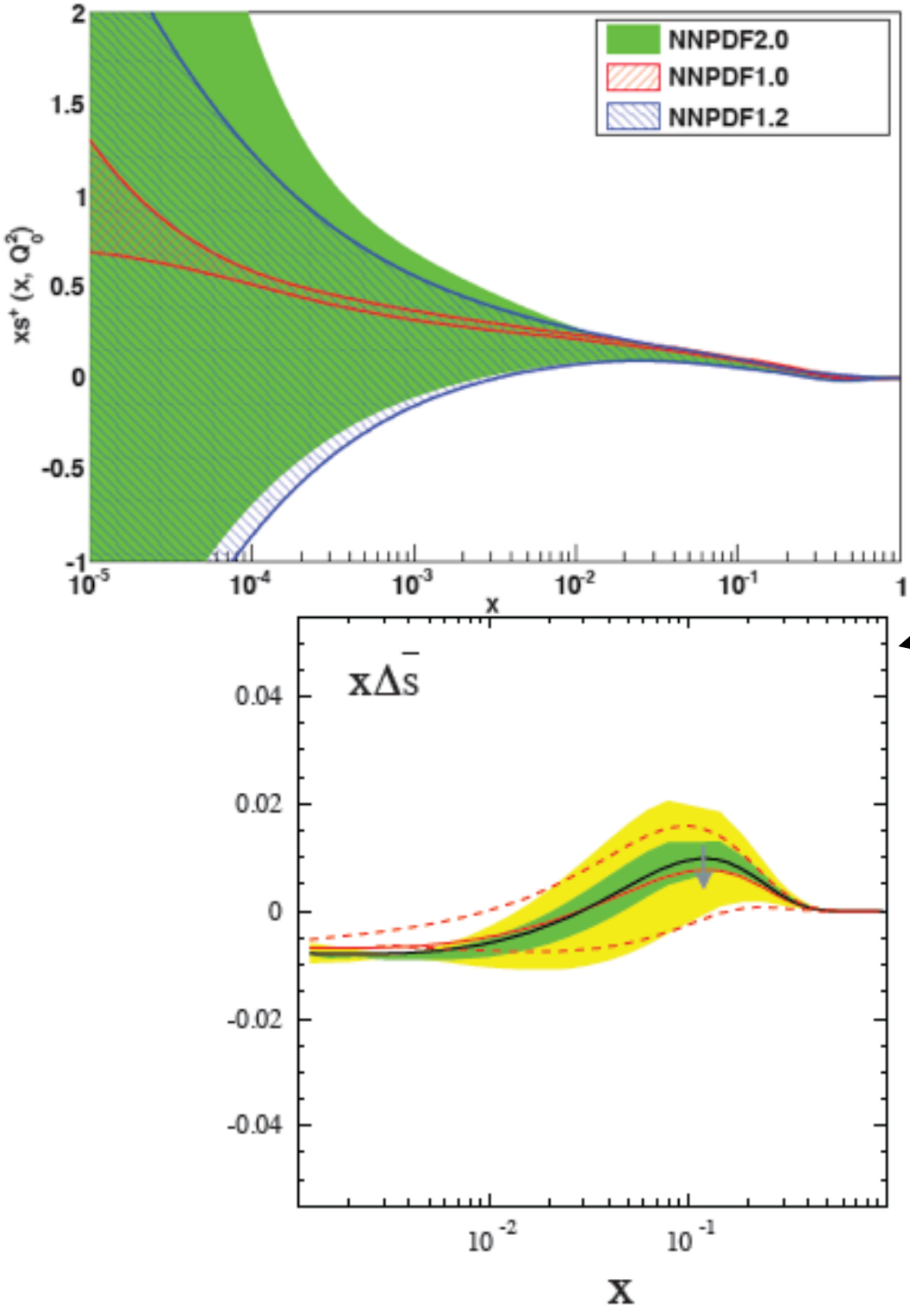
- Generalised parton distributions (GPDs)
  - transverse spatial distribution





- Transverse-momentum-dependent distribution functions (TMDs)
  - transverse momentum distribution

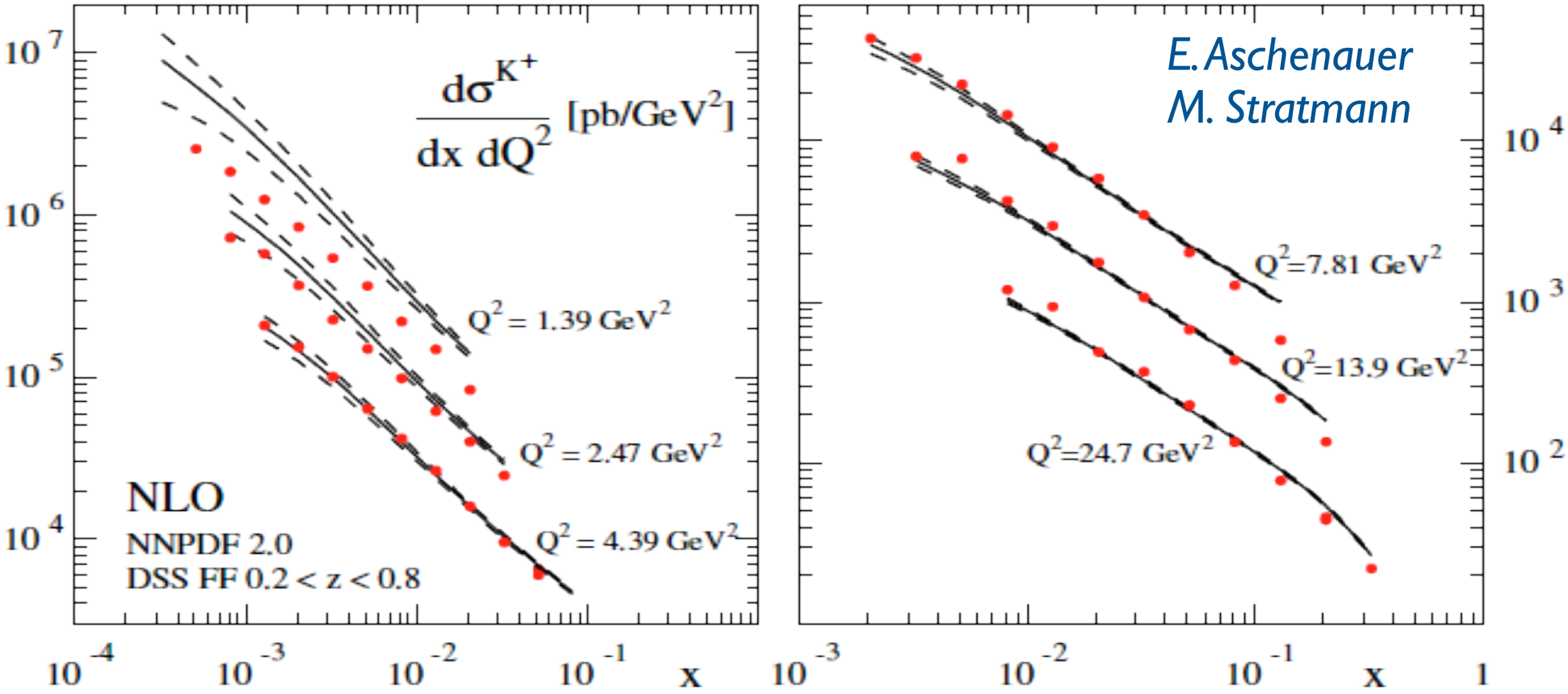
Sea quarks



- Distributions uncertain
- esp. strange sea unpolarised & polarised.
- Flavour separation
  - SIDIS
  - Variety of hadrons π^+, π^-, K^+, K^-...

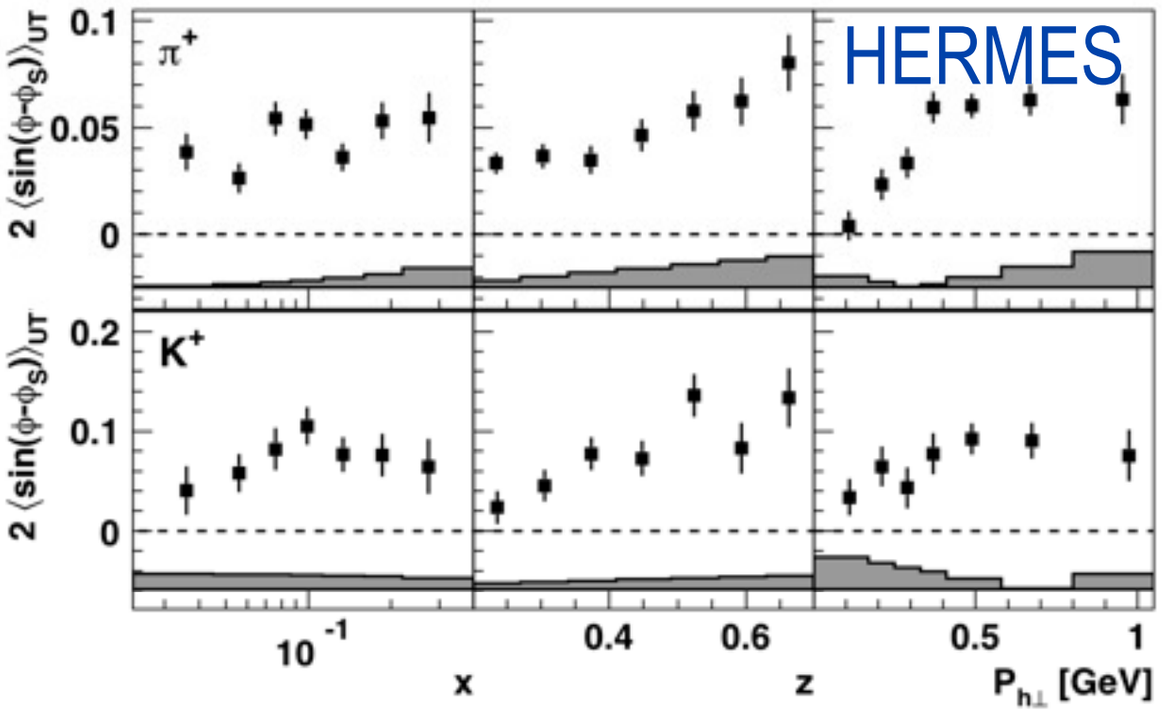
First study

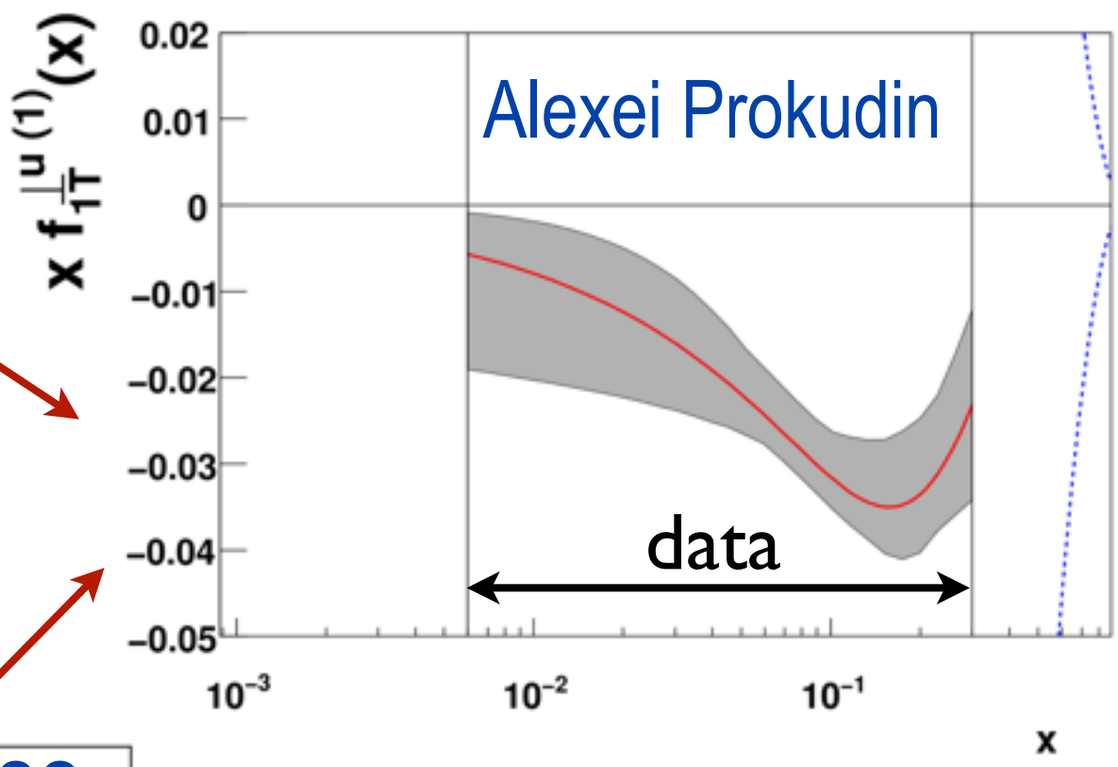
- Can we use MC to simulate psuedodata?
- PYTHIA vs. NLO calculation

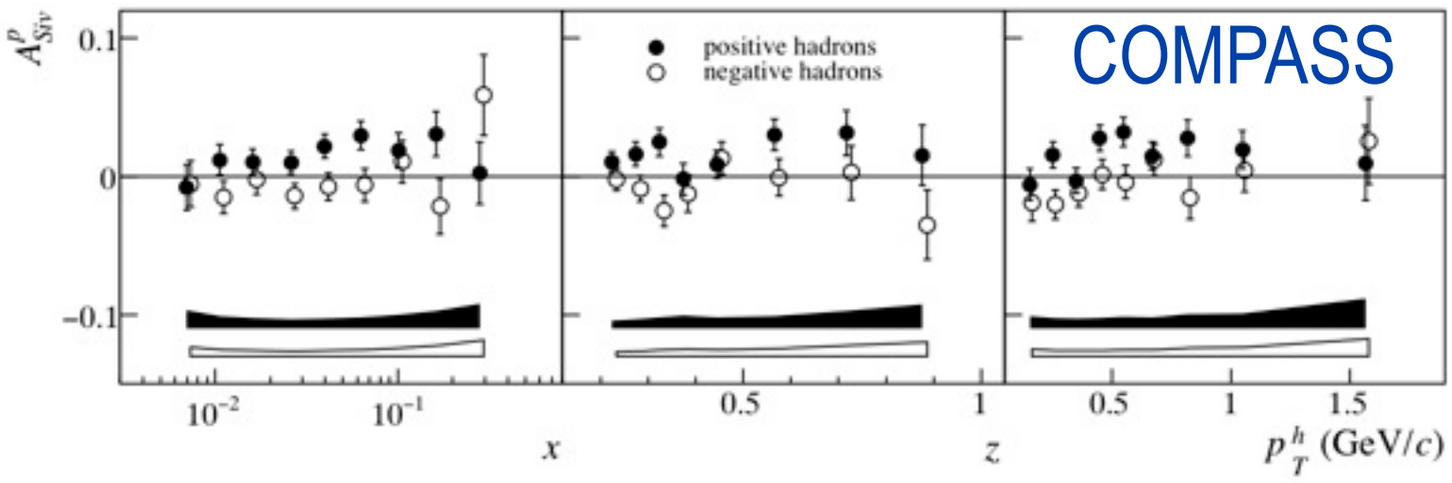


➡ Good agreement

TMDs

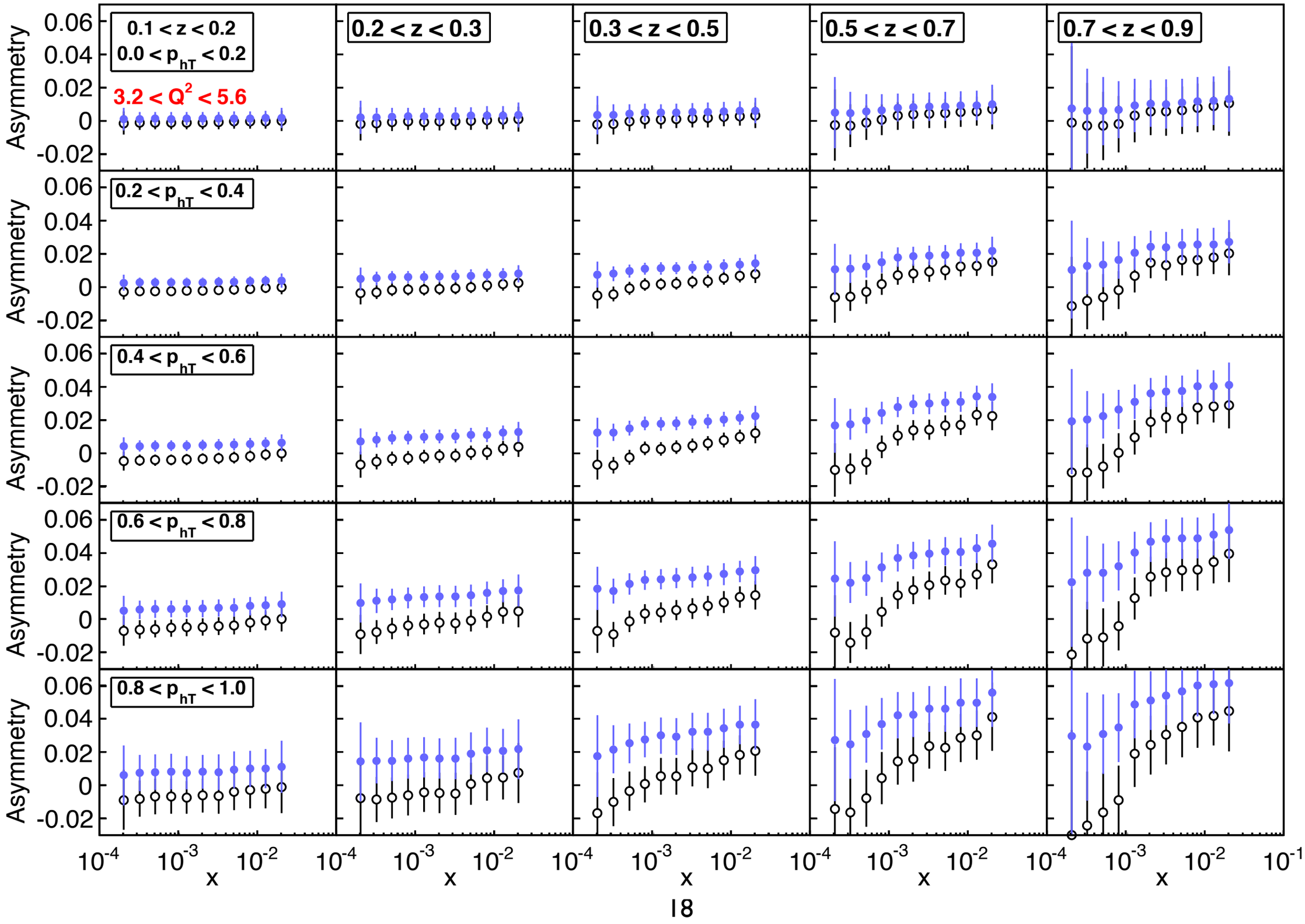

HERMES
π^+
K^+
$2\langle\sin(\phi-\phi_S)\rangle_{UT}$
0.1
0.05
0
0.2
0.1
0
10^{-1}
x
0.4
0.6
z
0.5
1
$P_{h\perp}$ [GeV]


Alexei Prokudin
$x f_{1T}^{\perp u\,(1)}(x)$
0.02
0.01
0
−0.01
−0.02
−0.03
−0.04
−0.05
data
10^{-3}
10^{-2}
10^{-1}
x

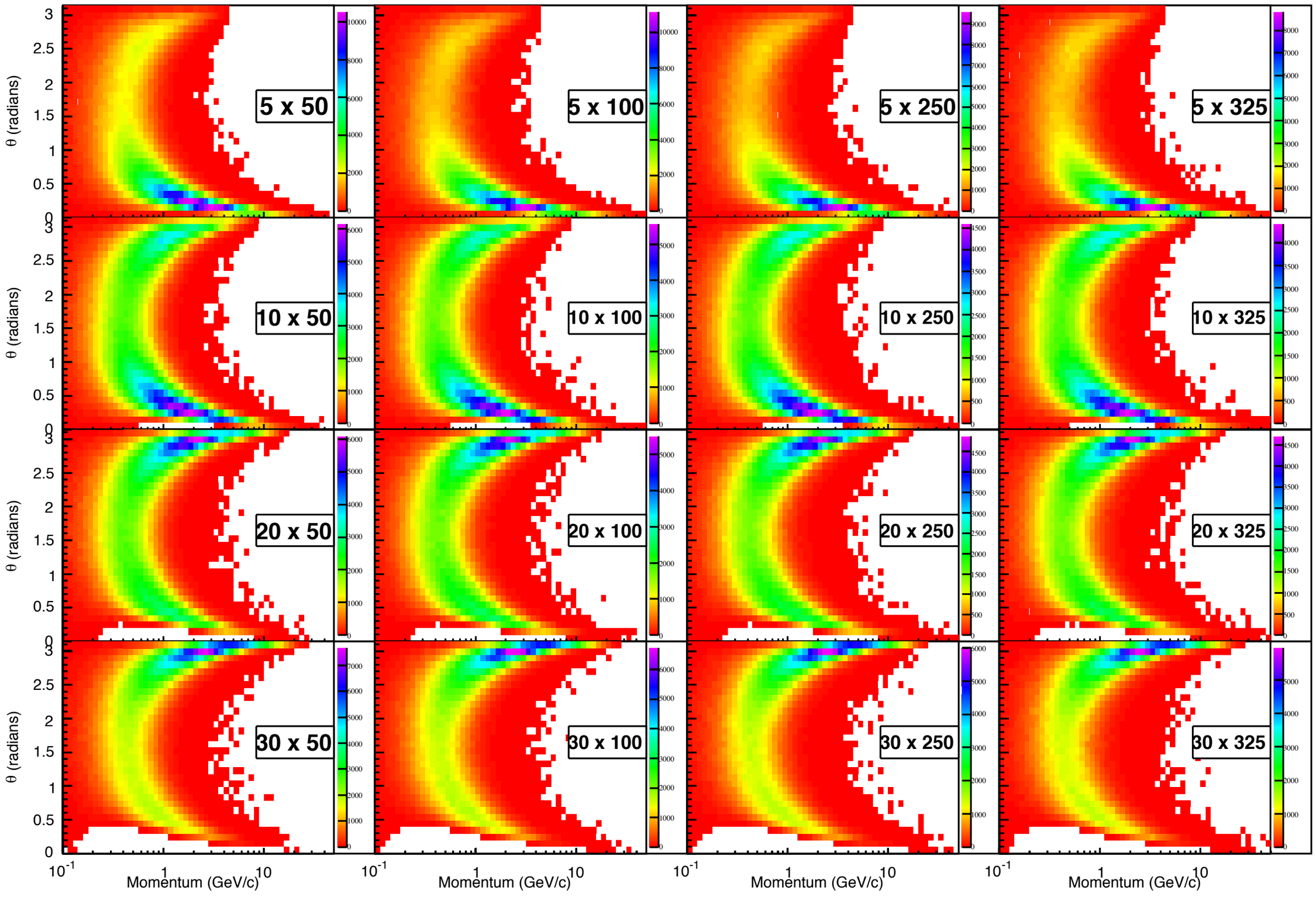

COMPASS
positive hadrons
negative hadrons
A_{Siv}^{p}
0.1
0
−0.1
10^{-2}
10^{-1}
x
0.5
1
z
0.5
1
1.5
p_T^h (GeV/c)

Sensitivity to sea q

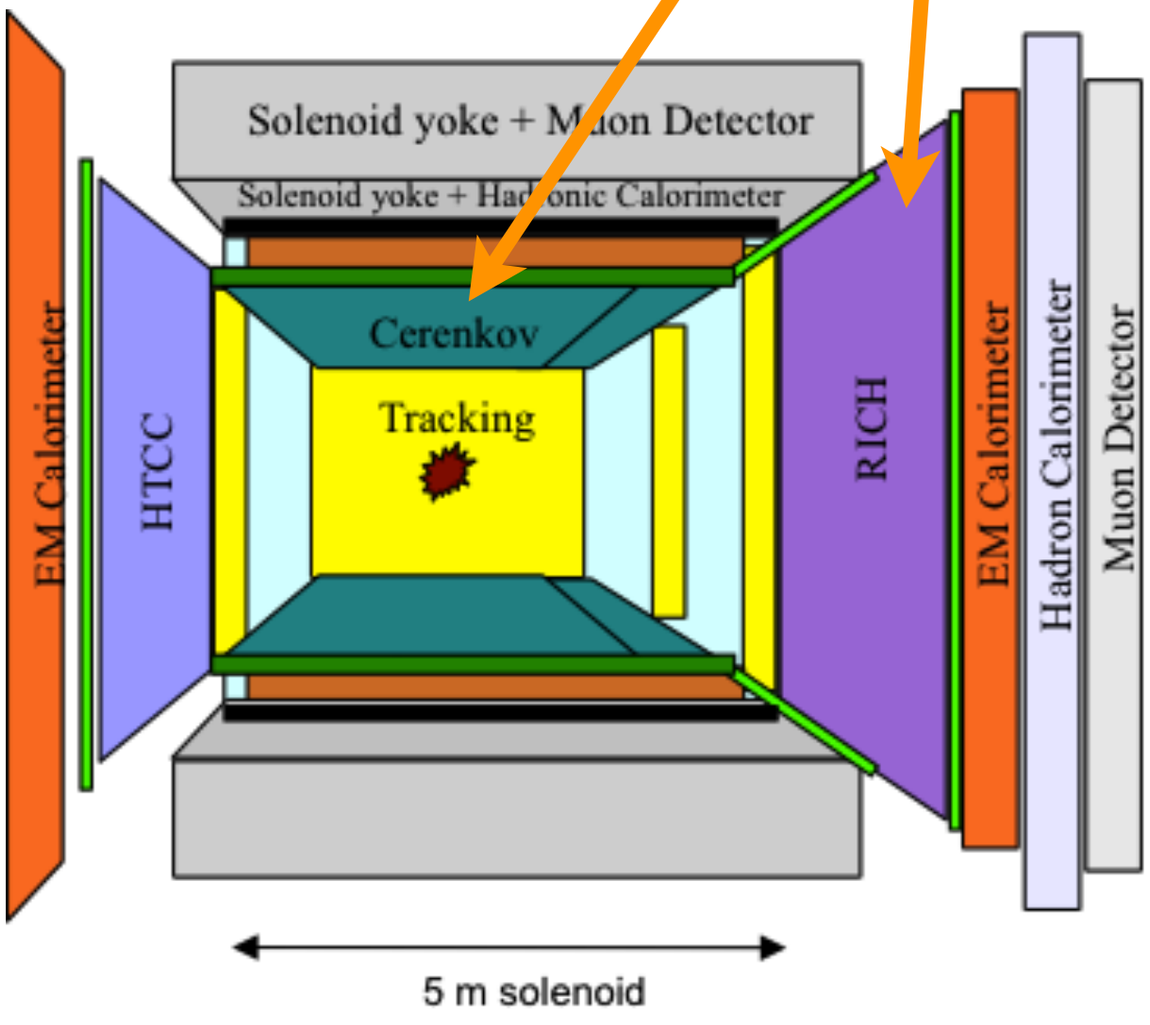
K^+ 4 fb^{-1}
20 x 250

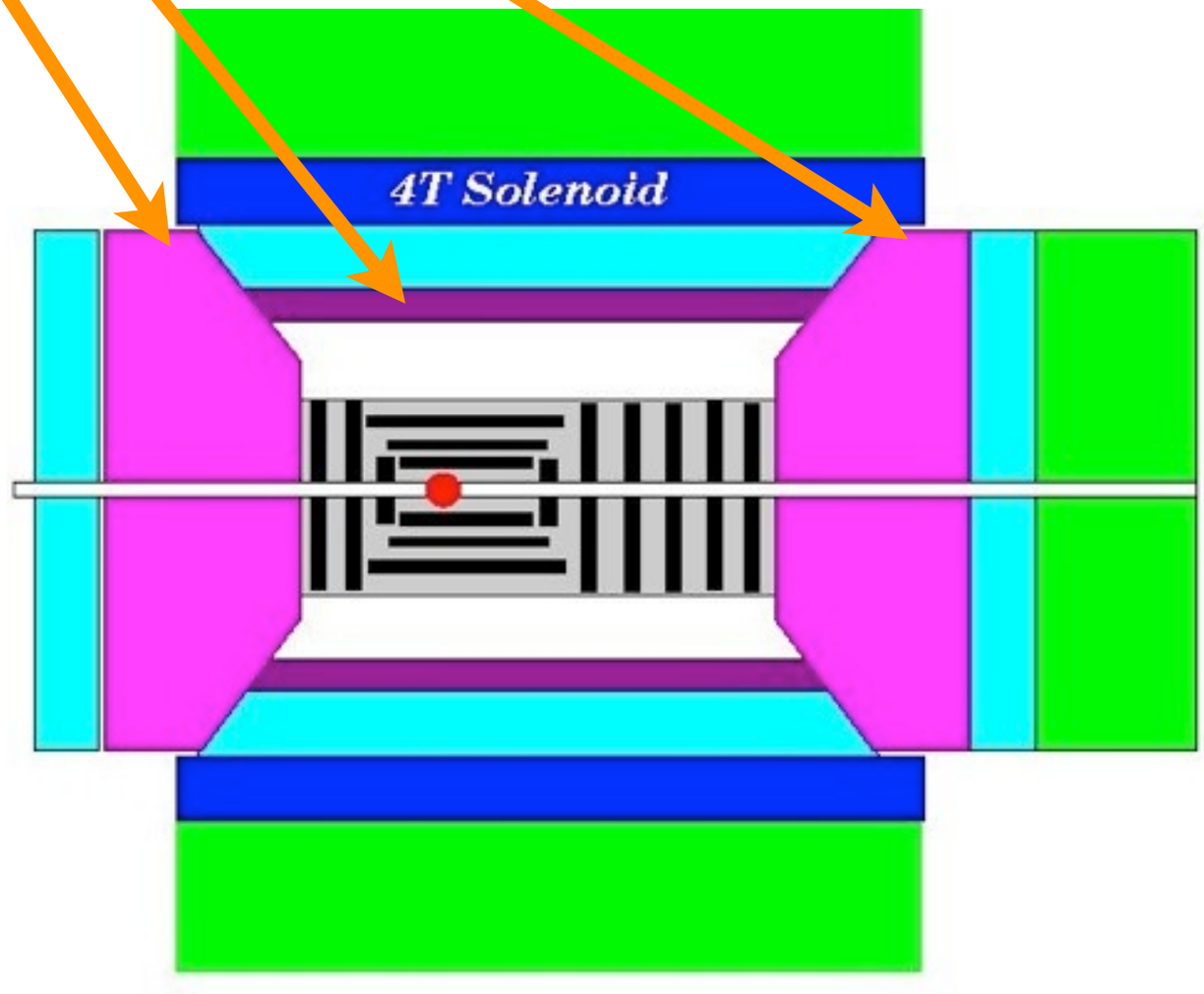


PID coverage: π



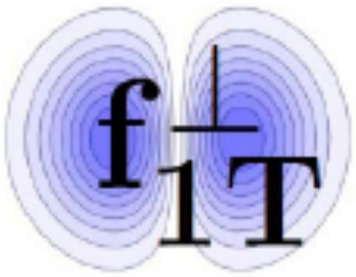
PID

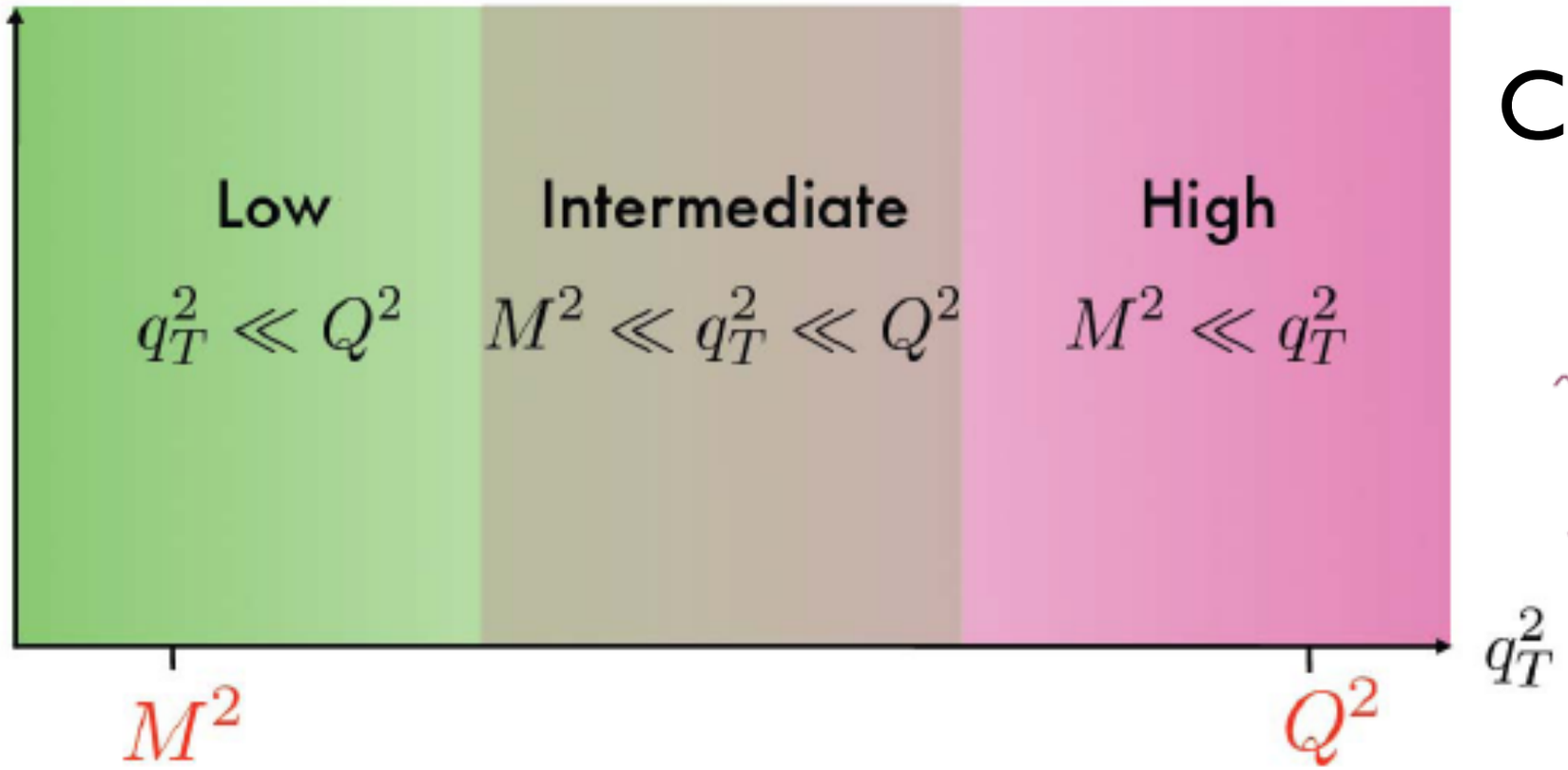

Solenoid yoke + Muon Detector
Solenoid yoke + Hadronic Calorimeter
Cerenkov
Tracking
EM Calorimeter
HTCC
RICH
EM Calorimeter
Hadron Calorimeter
Muon Detector
5 m solenoid


4T Solenoid

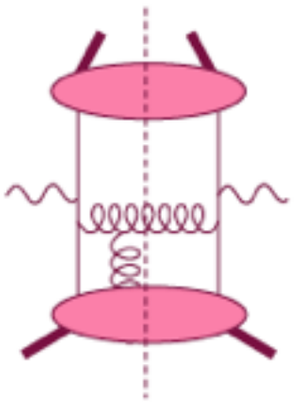
TMD to collinear factorisation: p_T

TMD





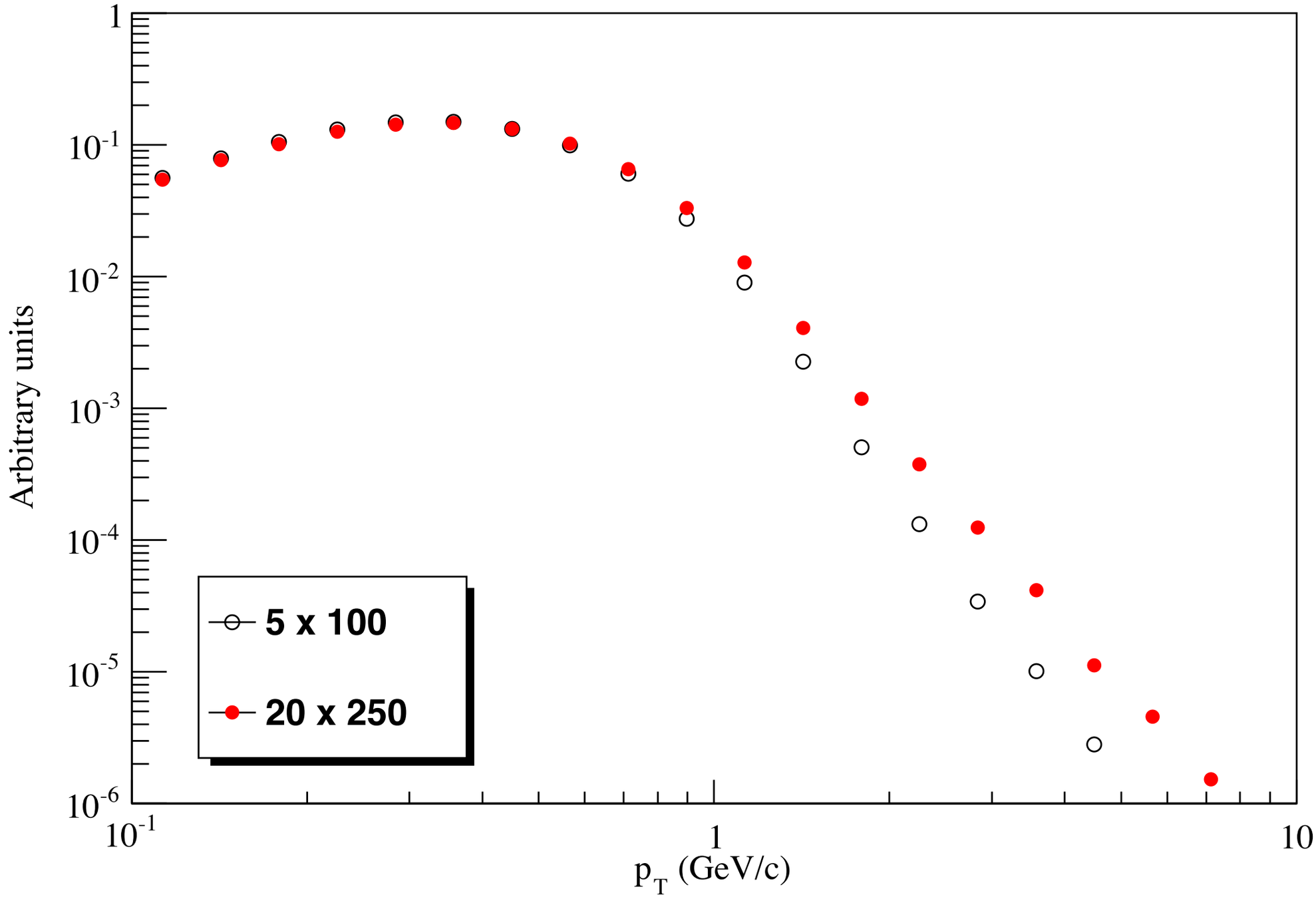
Collinear



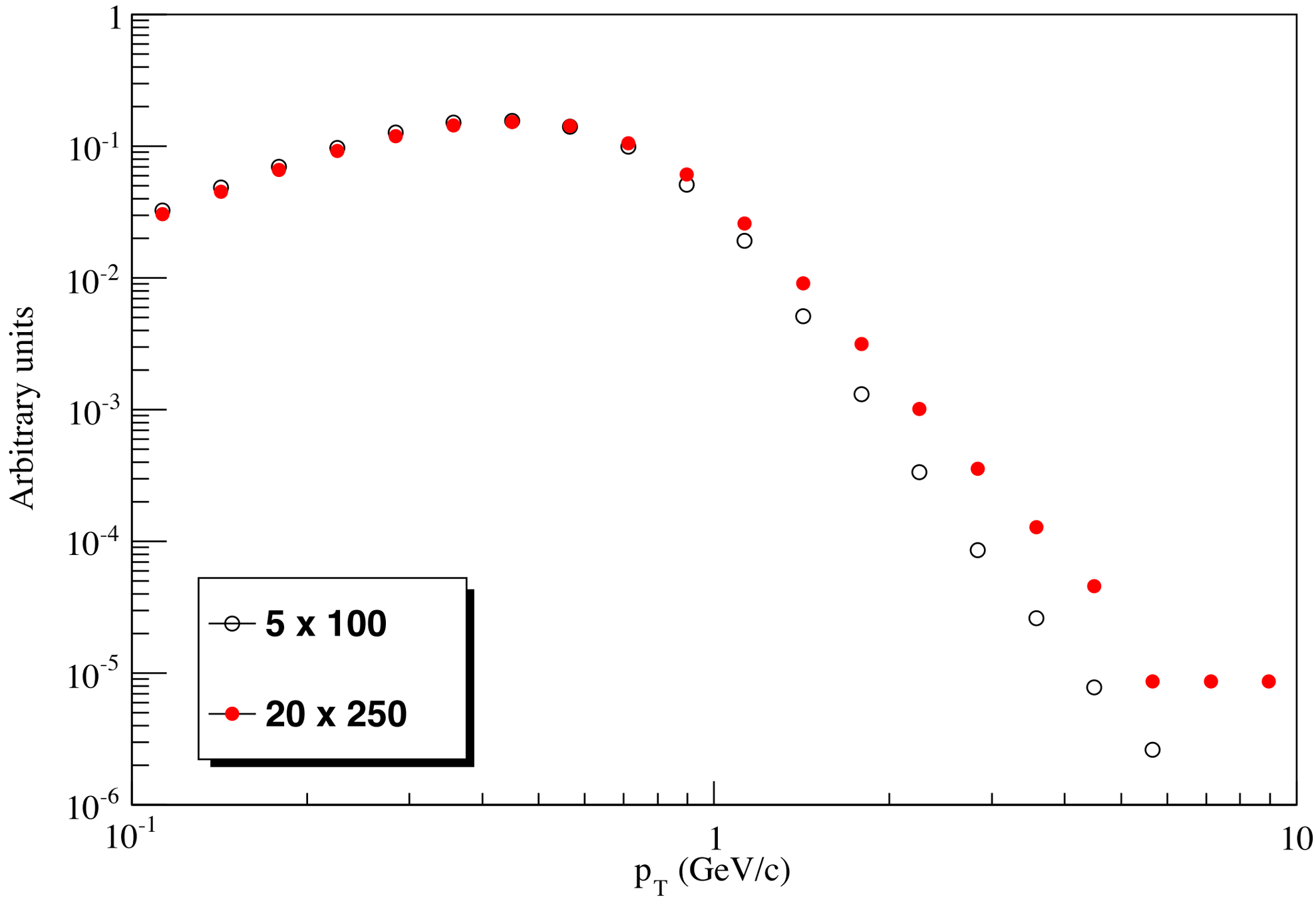
- Current SIDIS: low p_T
- EIC: wide p_T range

➡ explore TMD, collinear regime & overlap

PYTHIA: $\pi^{\pm}$ p_T

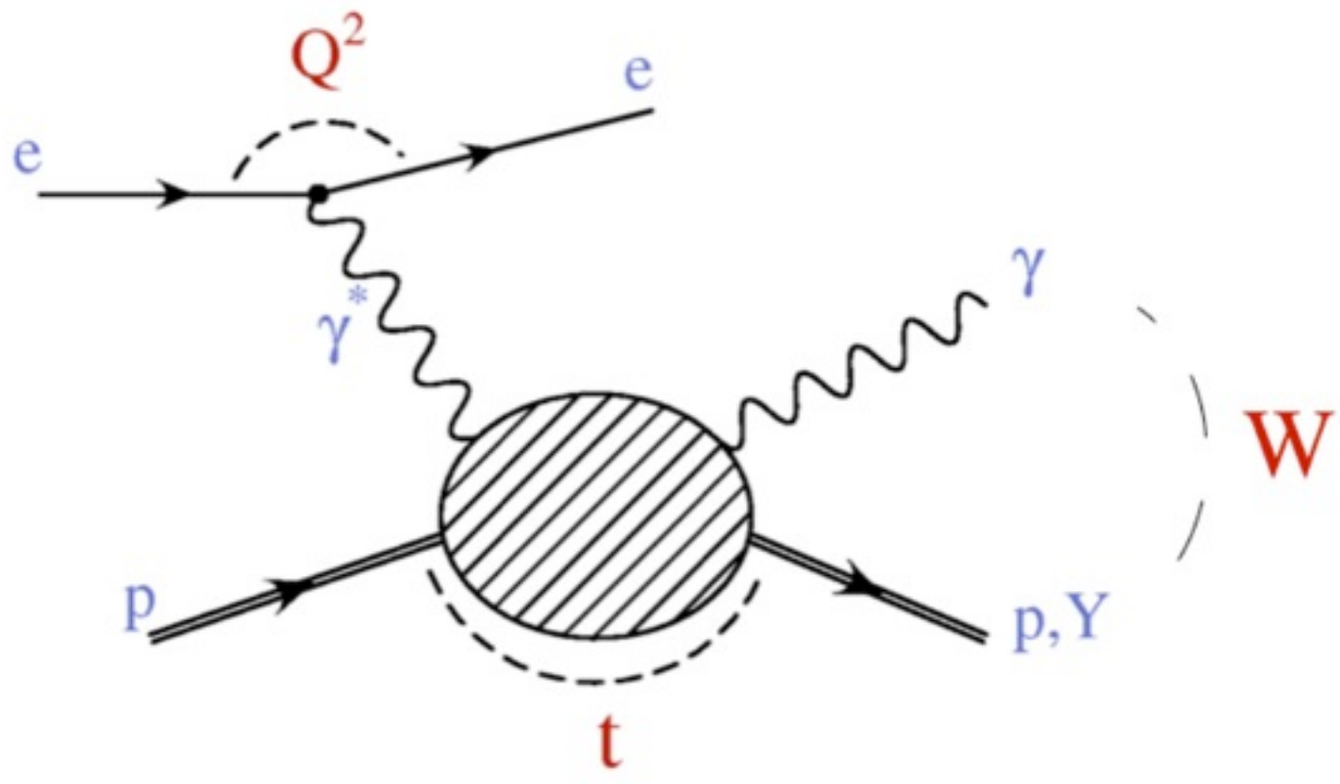


PYTHIA: $K^{\pm}$ p_T

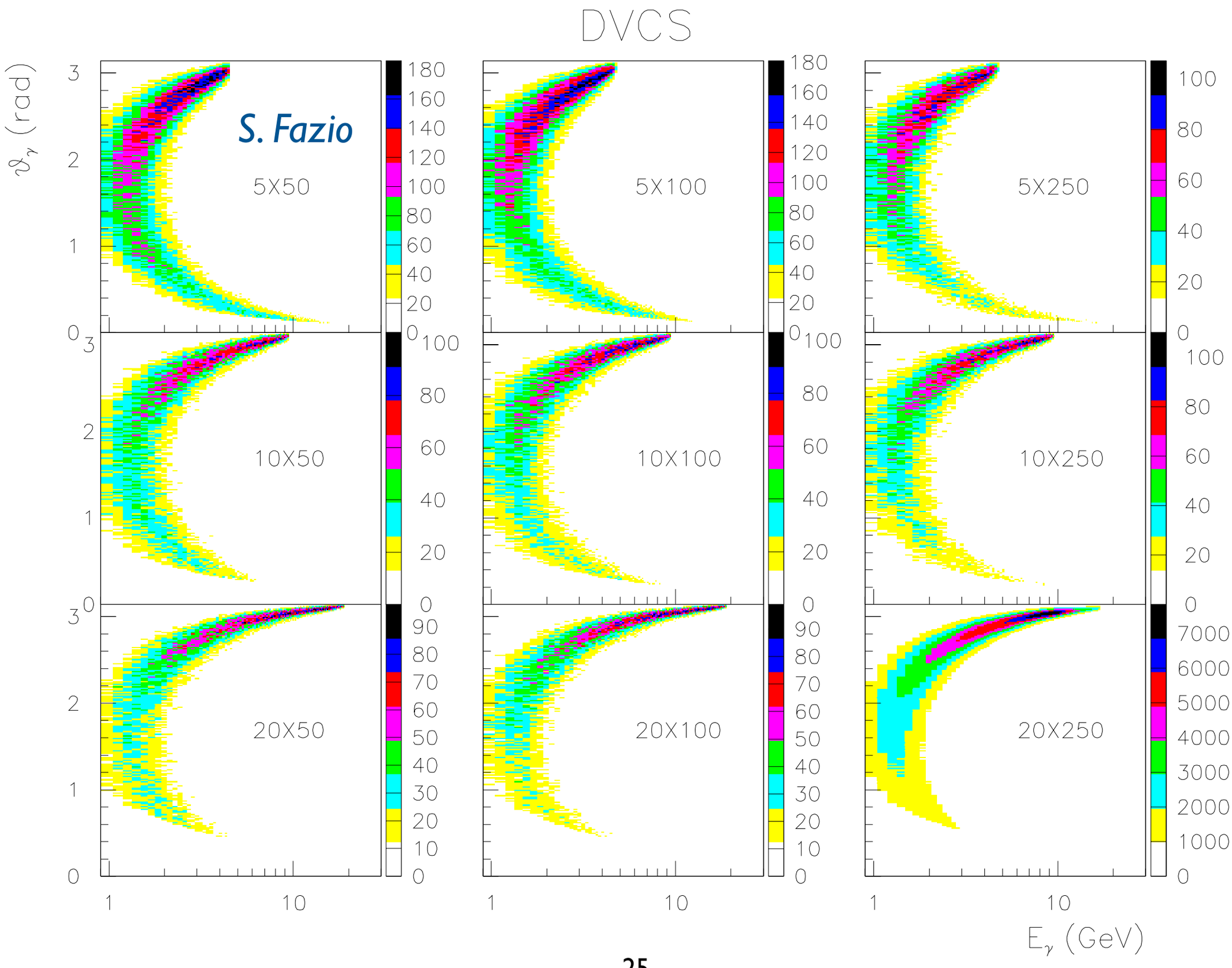


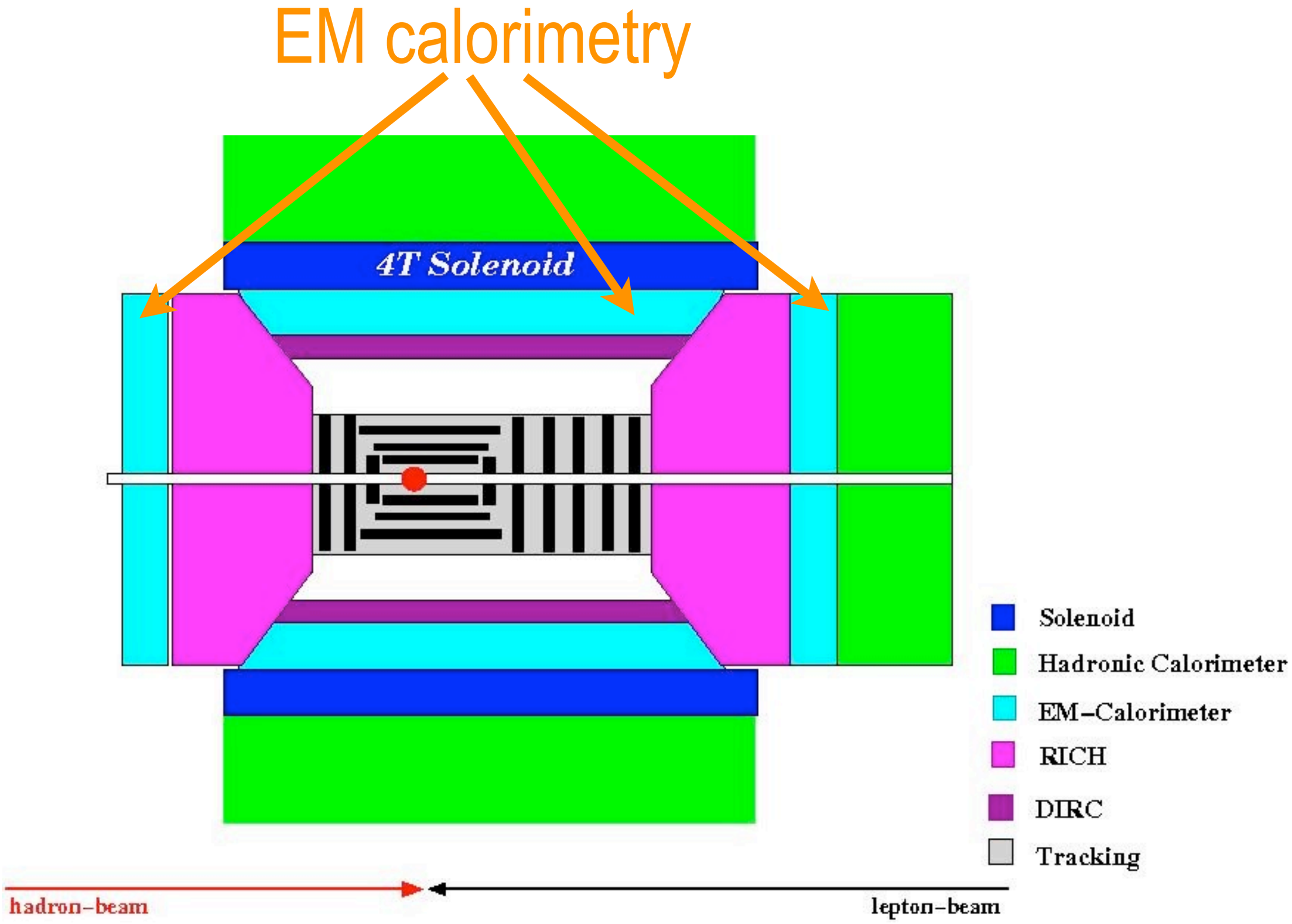
GPDs

- Accessible via exclusive processes
- e.g. deeply virtual Compton scattering (DVCS)

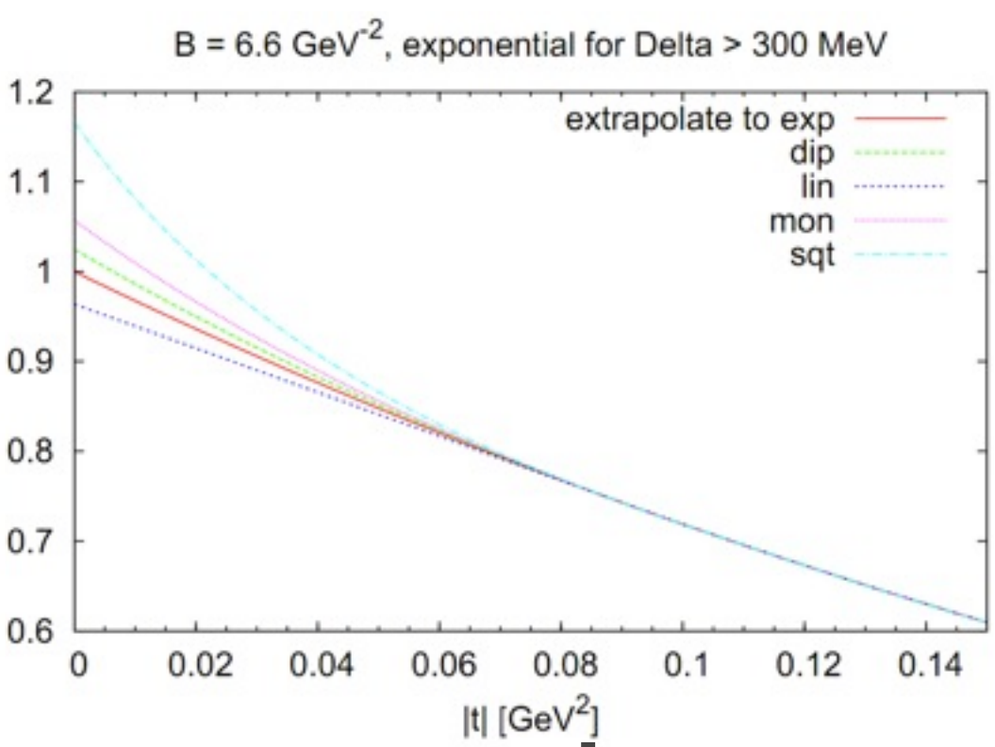


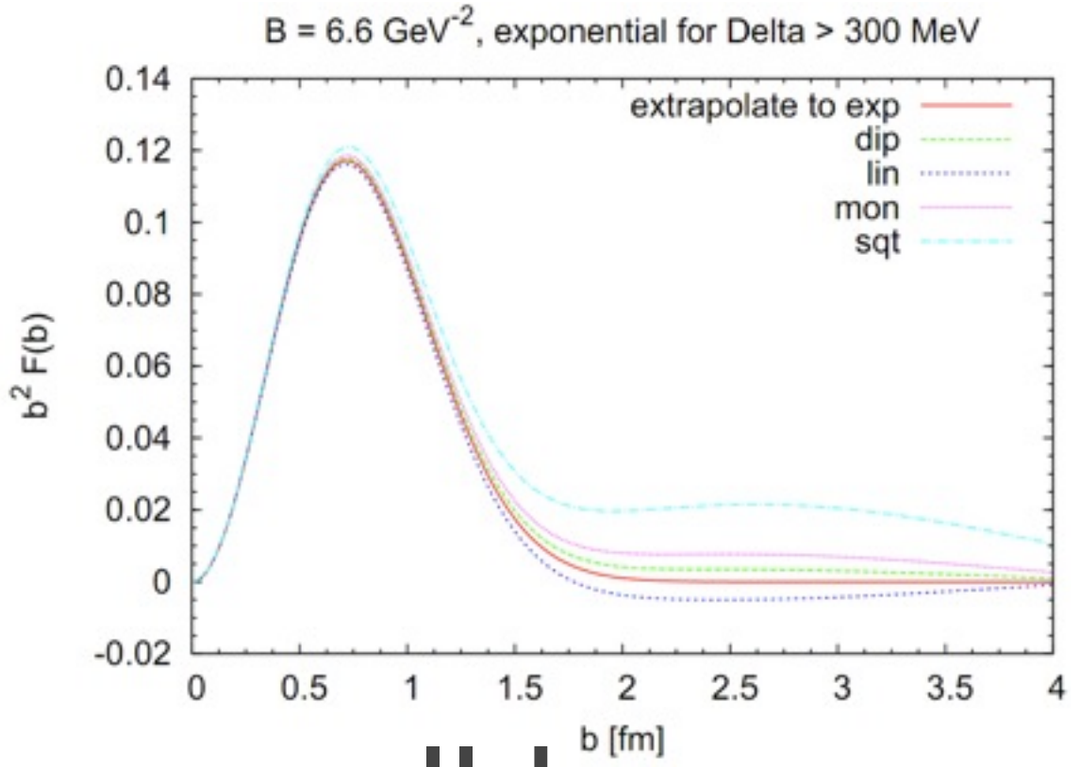
MILOU Monte Carlo generator



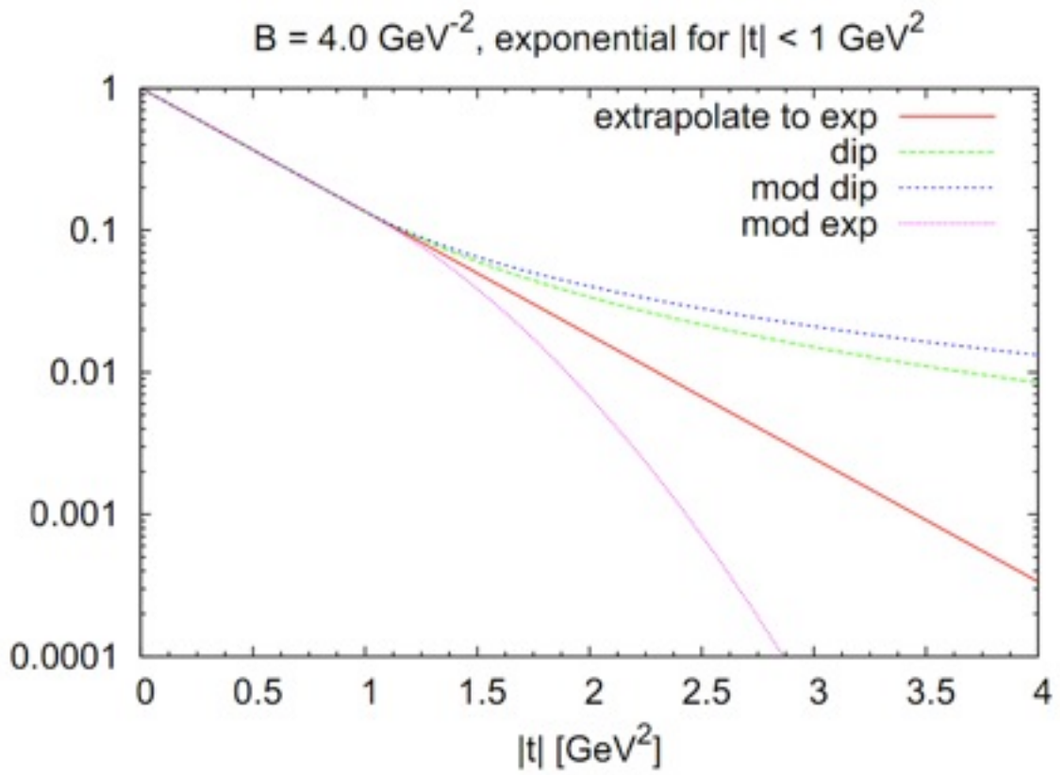

EM calorimetry
4T Solenoid
Solenoid
Hadronic Calorimeter
EM–Calorimeter
RICH
DIRC
Tracking
hadron–beam
lepton–beam

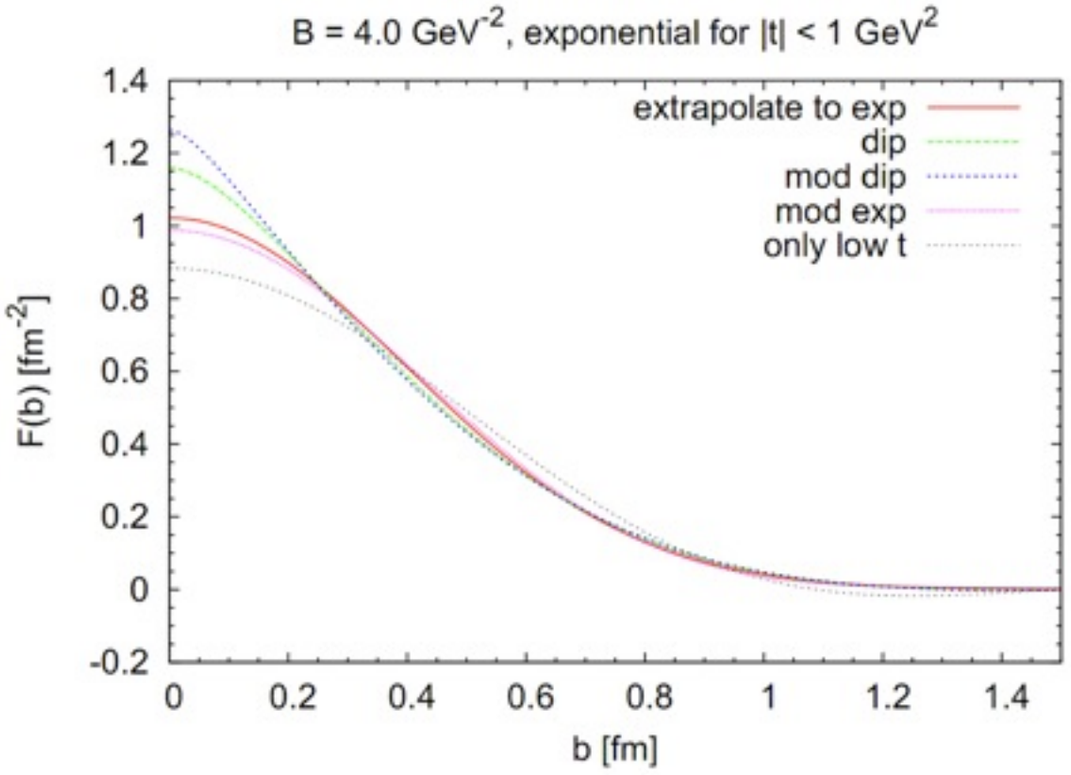
Small t - large b

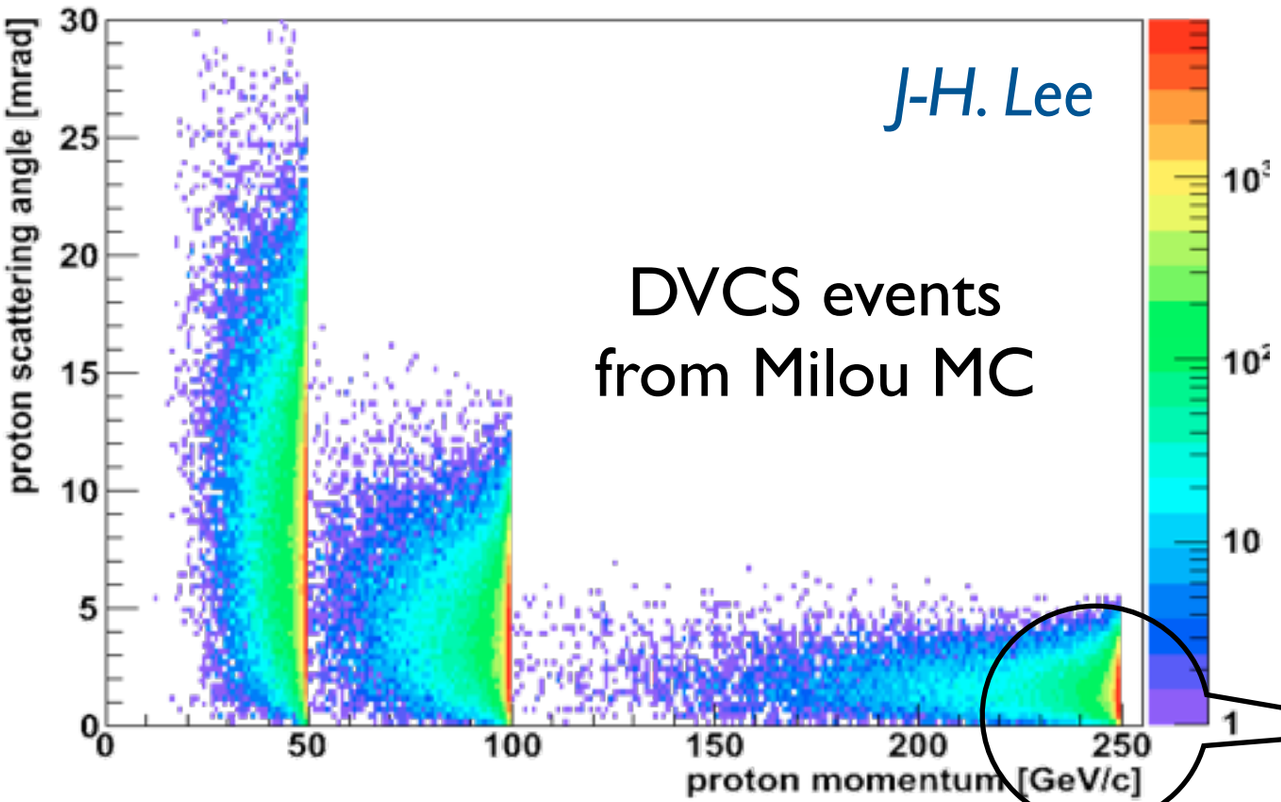


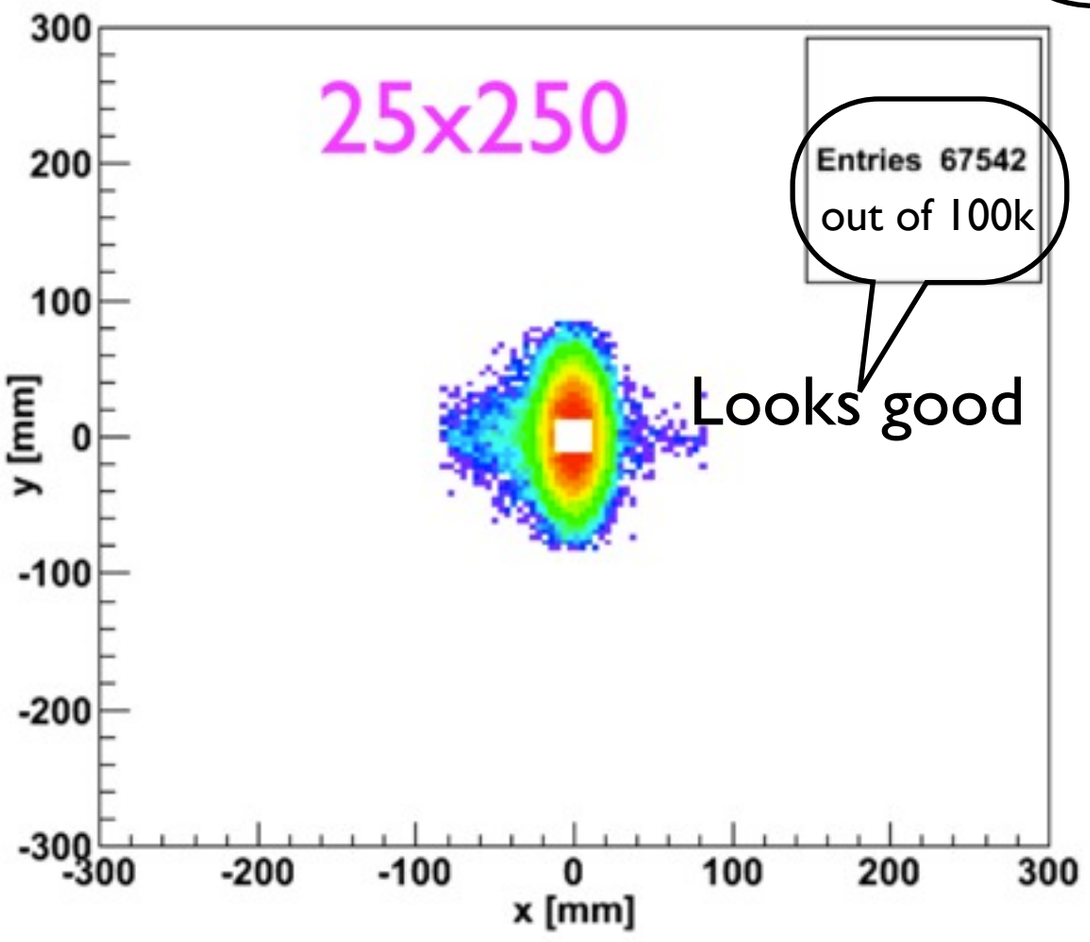


Large t - small b







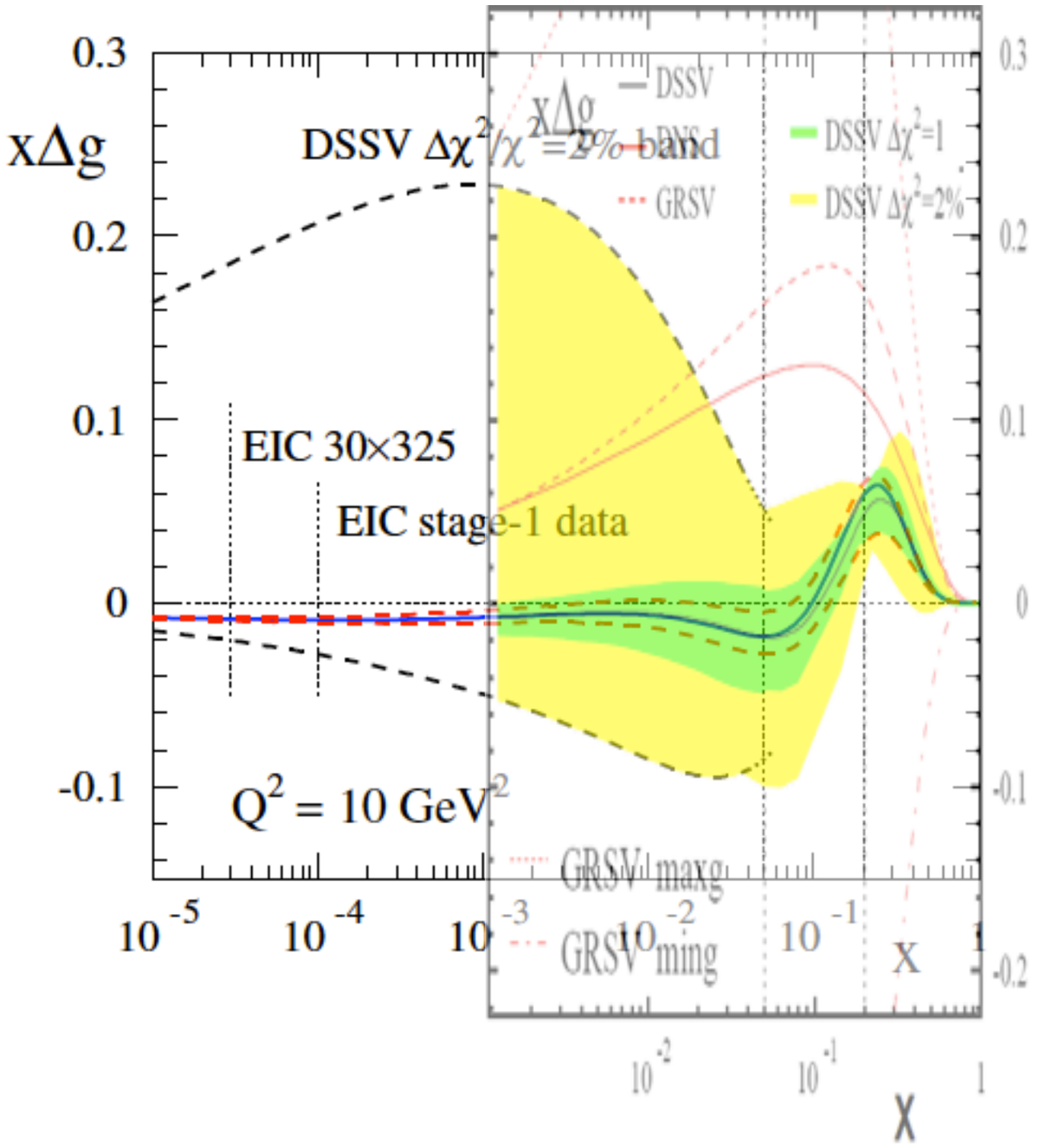


- Detect *e*, *p* & γ
  - Demands on detector & IR
- Roman pot detector needed for proton
- t acceptance:
  - beam envelope
  - magnet apertures

Summary

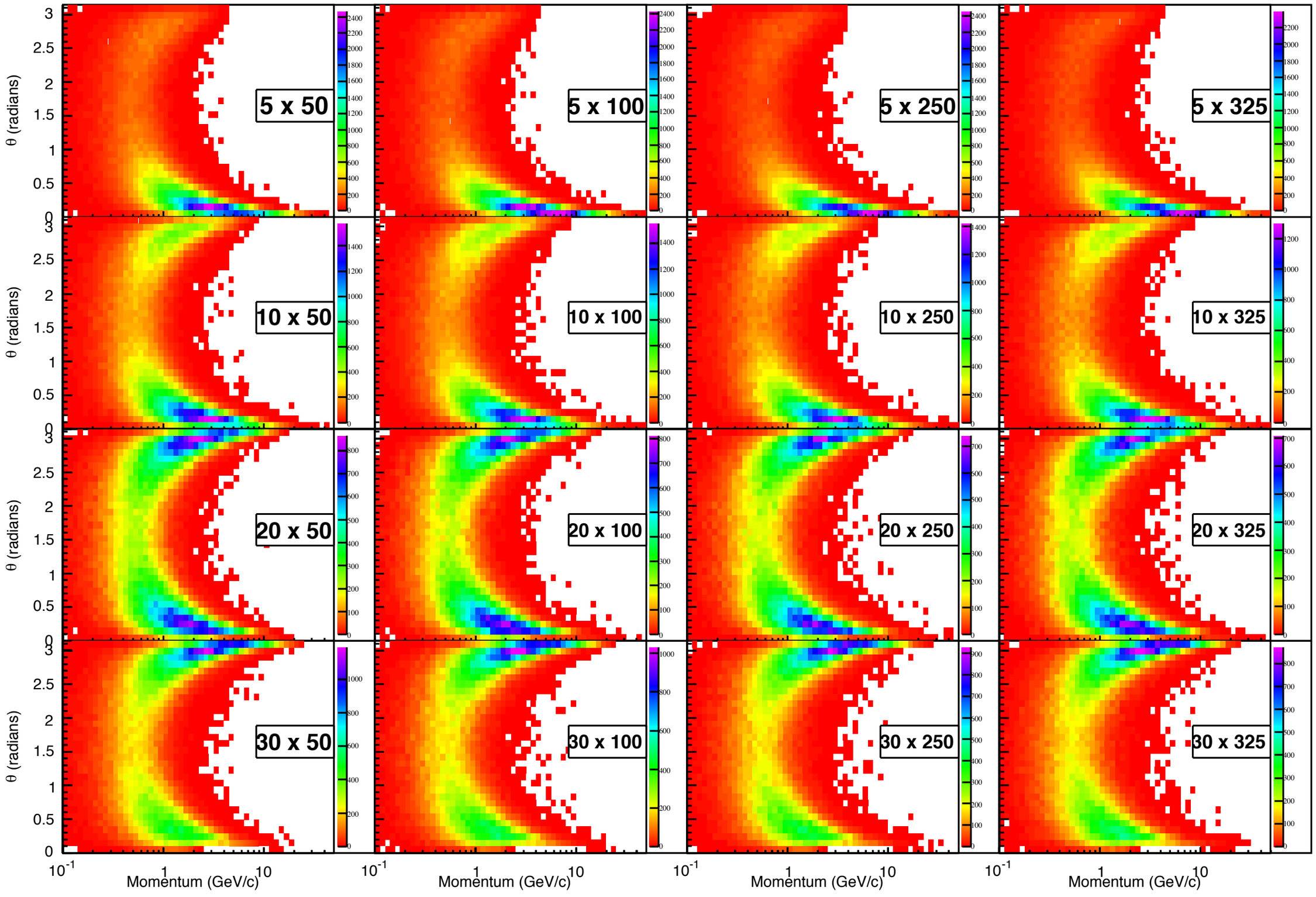
- ... blah...

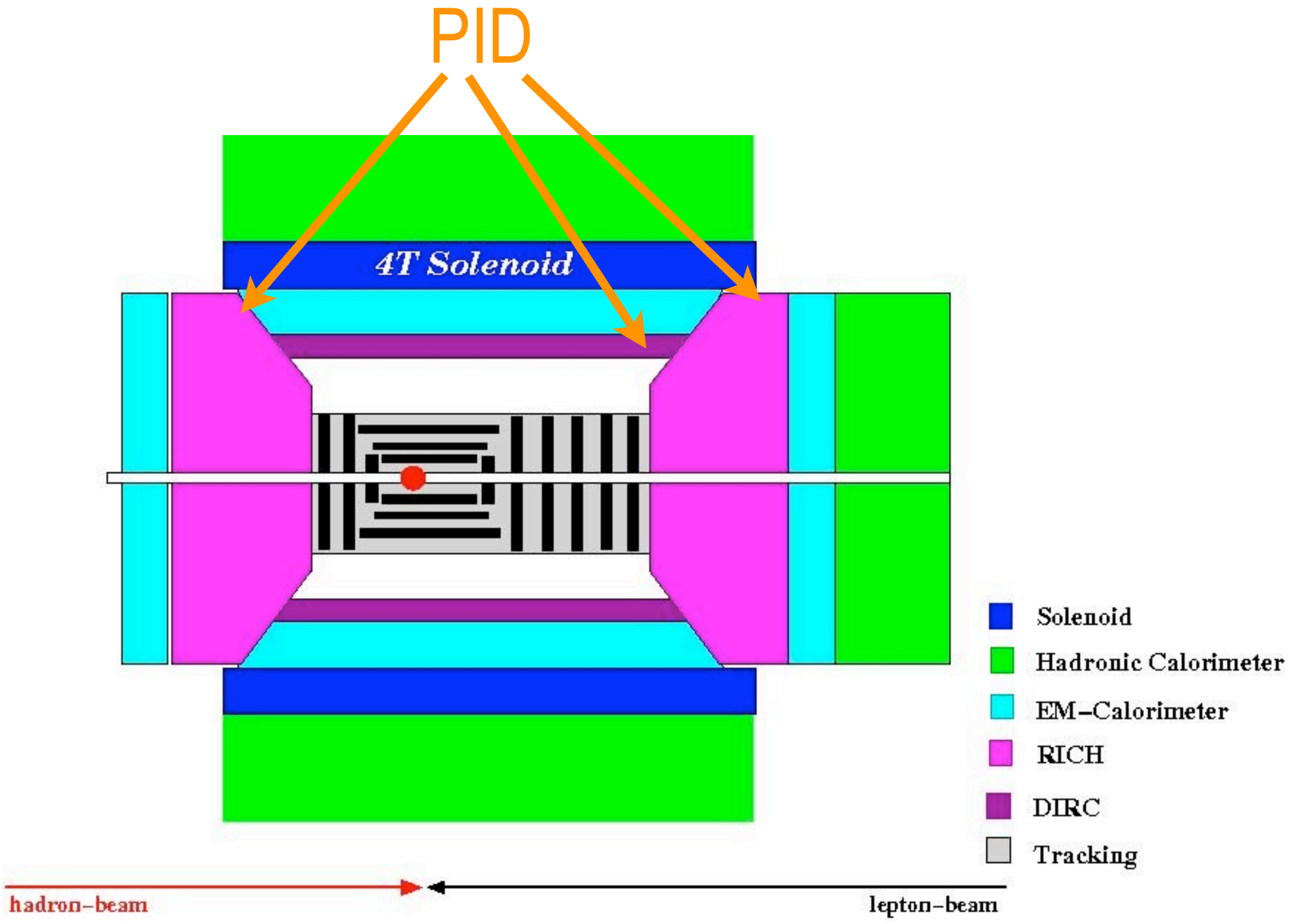
Additional


xΔg
DSSV Δχ²/χ² = 2% band
DSSV
GRSV
DSSV Δχ²=1
DSSV Δχ²=2%
EIC 30×325
EIC stage-1 data
Q² = 10 GeV²
GRSV maxg
GRSV ming
X


Good news, everyone!

PID coverage: K

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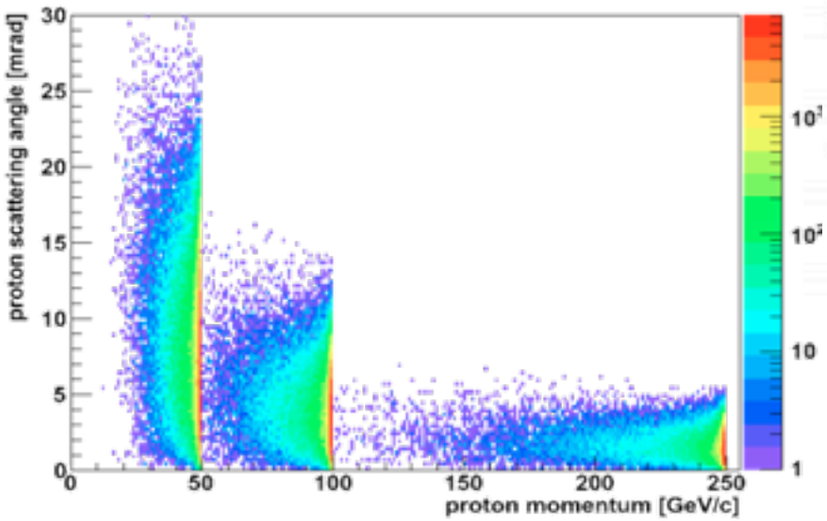

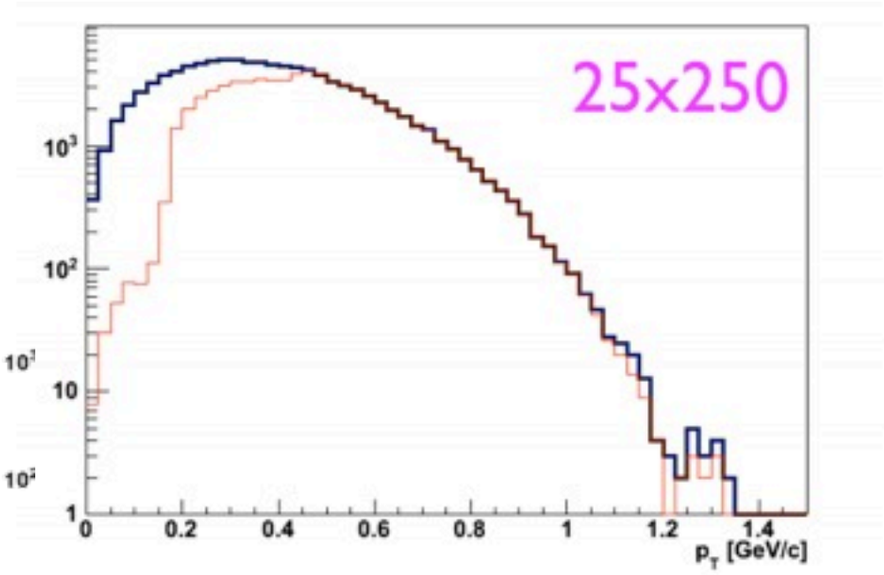

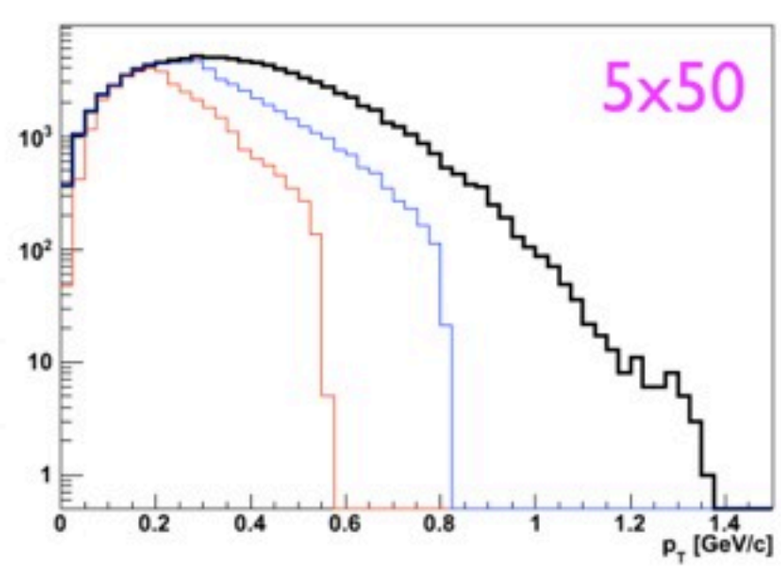

— Generated

— Quad aperture limited

— RP (at 20m) accepted